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Gender and Physical Training Effects on Soldier Physical Competencies and Physiological Strain

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ABSTRACT

We investigated the physical and occupational capabilities of male and females soldiers before and after 12 weeks of specialised physical training. The Combat Fitness Assessment (CFA) was employed to assess the infantry-related occupational capabilities, which consisted of a 15-km march at 5.5 km/h followed by the Run-Dodge-Jump (RDJ) activity. All soldiers (35 males and 28 females) carried 34.6 kg, which was based on the requirements for a 3-day operation. Physiological assessments of muscular strength and endurance, and aerobic and anaerobic capacities were also performed. All males could complete the RDJ in a rested state, prior to the march, whereas the majority of females (57%) could not complete the RDJ with weapon and webbing. The majority of males (91%) completed the 15-km in 165 min, whereas fewer females could complete the march successfully (36%). All infantry soldiers and the majority of combat-corps soldiers (79%) could complete the post-march RDJ in less than 70 sec, whereas the fastest female required 73 sec to complete the course. The specialised physical training improved strength and aerobic capacity for the female group and strength only for the male group, although the female scores remained below those of the males. These improvements did not translate into improved success in the infantry-based CFA task, i.e. no female could pass the 70-sec RDJ barrier. Post-specialised physical training one female completed the post-march RDJ in 73 sec, while another Control female achieved an RDJ time of 65 sec after the physical training period. Therefore, assuming that this small sub-group of female soldiers are representative of the whole Army, it is likely that a small number of female soldiers are physically able to complete this assessment within the same performance limits as current infantry soldiers. The elevated environmental heat stress encountered during the post-specialised physical training CFA potentially masked any possible benefit gained from the physical training program. Combined with the dramatic drop in soldier numbers it is difficult to provide definitive conclusions as to the effectiveness of the specialised physical training program. CFA administration should be planned for the cooler less humid months to diminish the likelihood of thermal injuries. If the CFA is conducted in hotter and more humid conditions, longer completion times (allowing rest periods), reduced distance and lighter loads should be considered.

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Executive Summary

The Australian Defence Force (ADF) has endorsed the position of 'The review of the Employment of Women in the ADF' agendum that the ADF employment policy is to be competency based. Head Defence Personnel Executive (HDPE) has been tasked to determine the physical standards for the ADF Combat Arms, to the extent necessary to determine whether women should be employed in these work areas. Consistent with these priorities, the Director General Defence Health Service (DGDHS) has tasked the Defence Science & Technology Organisation (DSTO) - to investigate the separate and combined effects of gender, load carriage and thermal environment on soldiers' work performance and physiological strain. This investigation employed the Combat Fitness Assessment (CFA) consisting of a 15-km march at 5.5 km/h followed by the Run-Dodge-Jump (RDJ) activity. All soldiers (35 males and 28 females) carried 34.6 kg, which was based on the requirements for a 3-day operation. While it was evident that some soldiers, particularly the smaller females, would find it difficult to complete this task in the required time, due to the physiological demands, a 12-week specialised physical training program was implemented. A Control group was also included in which soldiers continued with their typical physical training regimen. This training phase was included to establish whether given sufficient physical training, females could complete an infantry-based task at an equivalent level to their male counter parts. Physiological assessments of muscular strength and endurance, and aerobic and anaerobic capacities were performed before and after the 12-week physical training program to ascertain the effectiveness of the program.

Before the specialised physical training was implemented, males exhibited greater muscular strength and endurance, and aerobic and anaerobic capacities compared with females. All males could complete the RDJ in a rested state, prior to the march, whereas the majority of females (57%) could not complete the RDJ with weapon and webbing. The majority of males (91%) completed the 15-km in 165 min, whereas fewer females could complete the march successfully (36%). All infantry soldiers and the majority of combat-corps soldiers (79%) could complete the post-march RDJ in less than 70 sec, whereas the fastest female required 73 sec to complete the course.

The specialised physical training improved strength and aerobic capacity for the female group and strength only for the male group, although males still possessed higher levels of strength and aerobic capacity compared with the females. However, these improvements did not translate to enhanced power, muscular endurance and anaerobic capacity. Furthermore, the Specialised Training Group (STG) males and females exhibit small, if any, improvements in the infantry-based task, i.e. no female could pass the 70-sec RDJ barrier. In fact some soldiers exhibited decrements in CFA performance. One STG female completed the post-march RDJ in 73 sec, while another Control female achieved an RDJ time of 65 sec after the physical training period. Therefore it is likely that a small number of female soldiers are physically able to complete this assessment at the same performance level as current infantry soldiers.

The elevated environmental heat stress encountered during the post-specialised physical training CFA potentially masked any potential benefits gained from the physical training program.

A number of limitations need to be considered when interpreting the data pertaining to the specialised physical training; injury-illness (15%), reposting (9%) and deployment (76%) dramatically reduced the subject groups from 20 to 6 for STG females, 8 to 2 for Control females, 21 to 9 for STG males and 15 to 4 for Control males. Environmental conditions were significantly different between the pre- and post-specialised physical training assessments (WBGT: 19°C vs. 26°C). Most soldiers were in a relatively de-trained physical fitness status at the time of the initial assessment due to recently returning from Tandem Thrust and associated post-exercise leave. Subsequently, the improvement of the Control female was likely a result of her own personal physical training regimen being reinitiated after the field exercise.

CFA administration should be planned for the cooler less humid months to diminish the likelihood of thermal injuries, which appeared to be the current general practise at 1 Brigade. If the CFA is conducted in hotter and more humid conditions, longer completion times (allowing rest periods), reduced distance and lighter loads should be considered. Prevailing injuries and illnesses need to be critically reviewed prior to conducting a CFA or commencing operations or training. Further consideration is necessary to optimise current physical training structure, with respect to general physical fitness and trade-specific physical fitness. While it is recommended that a sufficient physical training program be implemented prior to the CFA, this rationale is contrary to the proviso that all soldiers should be able to achieve a minimum standard, which can be randomly assessed at any time. Issues relating to current CFA policy are discussed in Annex G, which includes rationale for implementing revised 2.4 km Basic Fitness Assessment (BFA) times as a screening tool prior to CFA administration. The inclusion of shooting and RDJ components at the end of the 15-km is recommended for high readiness infantry and associated trades, although the inclusion for all soldiers requires further deliberation.

Authors

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Mark graduated from the University of Wollongong with a BSc in Human Movement (1992), MSc in Thermal Physiology (1995) and PhD in Exercise/Thermal Physiology (1999). In 1998 Mark moved to the UK to conduct research in sweat gland physiology at the University of Strathclyde (Glasgow). In 2001 Mark retuned to Australia to join DSTO as a Research Scientist to evaluate physiological (especially heat-related) strain in ADF personnel, focussing on potential mechanisms for its reduction.

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Tony Lau graduated with a B.Sc (Hons) from the Chinese University of Hong Kong (CUHK), Hong Kong in 1979 majoring in Biology and Biochemistry. He obtained his M. Phil degree in environmental toxicology from the same University in 1981. Supported by a Croucher Foundation Scholarship (HK), he studied environmental toxicology at Melbourne University and was awarded a Ph.D. degree in 1987. After a short spell of employment with the Unipath Pathology Laboratory, he joined the then Materials Research Laboratory (MRL) in 1985 and conducted pharmacological studies leading to improved prophylaxis and therapy of nerve agents. He is currently a Senior Research Scientist managing a task in combatant performance. He was a member of a Human Science Review Team.

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The majority of Steve's 29 years service with the ADF has been as an Army Physical Training Instructor (PTI). The final 3 years as a PTI were in the capacity of Chief Implementation Officer (CIO, WO1) at the Australian Defence Force Physical Training School (ADFPTS), HMAS Cerberus. In 1997, as a Captain, he was appointed to the Directorate of Clinical Policy in the Defence Health Service Branch (DHSB). From 1999 to 2002 as a Major he worked as Staff Officer Injury Prevention, within Directorate of Preventive Health, DHSB. Currently Steve is a Staff Officer working in the Office of Chief of Army. Steve's academic qualifications include a Diploma of Sport and Recreation (1981), a Diploma of Teaching (1984), a Bachelor of Education PE (1986) and a Graduate Diploma of Exercise Science (1993), he is currently completing a Masters Degree in Public Health.

Contents

1. Introduction

The Chiefs of Staff Committee (COSC) of the Australian Defence Force (ADF) has endorsed the position of 'The review of the Employment of Women in the ADF' agendum that the ADF employment policy is to be competency based, and that competencies for all trades and critical mass limits be developed by the Head Defence Personnel Executive in support of the Service Chiefs. COSC has therefore tasked Defence Personnel Executive with determining Physical Employment Standards for the ADF Combat Arms, to the extent necessary to determine whether women should be employed in these work areas. Consistent with these priorities, the Director General Defence Health Service has tasked the Defence Science & Technology Organisation (DSTO) to investigate the separate and combined effects of gender, load carriage and thermal environment on soldiers' work performance and strain. This investigation employed a field base trial to evaluate the strain experienced by soldiers during the commonly employed annual Combat Fitness Assessment (CFA), consisting of a 15-km march being completed in 165 min (i.e. marching at 5.5 km/h). However, rather than differentiate the load mass carried by unit (combat vs. non-combat) and body mass for each soldier, a uniform load was carried by all soldiers, which was based on the requirements for a 3-day operation and consisted of 27.7 kg in webbing and pack, 3.6 kg weapon and 3.3 kg in clothing and boots, a total of 34.6 kg. This common mass allowed direct comparisons between combat and non-combat soldiers and their ability to perform an infantry-based task. Furthermore, while many soldiers may be able to complete the march in the required time, some may exhibit significant performance decrements in subsequent tasks due to the demands of the 15-km march. Of particular interest were the combat-related performance capabilities of the soldiers at the completion of the march, with a Run-Dodge-Jump (RDJ) and Weapons Training Simulation System (WTSS) shoot being performed at the end of the 15-km march. This trial endeavoured to obtain critical information pertaining to operational effectiveness of the combat soldier after a 15 km pack loaded march.

When examining the published literature it is evident that smaller female soldiers may find it extremely difficult to complete the 15 km in the prescribed time. Harper et al. (1997) reported that females could only march at a maximal speed of 4.4 ± 0.59 km/h when carrying 36 kg over a 10 km course and could only maintain the CFA marching pace when carrying 18 kg (5.4 ± 0.55 km/h). In addition, employing the predictive equation of Pandolf et al. (1977), a 60 kg female carrying a 34 kg load, marching at 5.5 km/h on a flat dirt road would expend 568 Watts. This energy expenditure, assuming a maximal oxygen consumption (Vo_{2max}) of 40 ml/kg/min (930 Watts), would require the soldier to be working at 63% of their Vo_{2max}, which is considerably higher than the commonly reported intensities of 35-45% when soldiers are directed to complete a set distance as fast as possible (Evans et al., 1980; Levine et al., 1982).

However, while the predictive equation, expressed by Pandolf and colleagues (1977), provides a good estimation of energy expenditure during the first 10-30 min of a march, energy expenditure seems to progressively increase as the march progresses, being 10-15% greater after 2-3 hr. Therefore, while this particular 60 kg female soldier would commence

the march at 63% Vo_{2max}, towards the end of the 165-min march the work intensity would have increased to ~72%. Typically, physically trained individuals can work at 40% Vo_{2max} for most of the day, 50% Vo_{2max} for about 3 hr, 60% Vo_{2max} for 2 hr and 70% Vo_{2max} for approximately 1 hr. Therefore those working at >60% Vo_{2max} would find it difficult to sustain this energy expenditure for 3 hr, would be at a greater risk of suffering from an injury/illness and would have limited physical capabilities at the end of the 15-km as a result of the exacerbated physical/physiological strain. However, it is uncertain whether these females in the previously reported study of Harper et al. (1997) were given physical conditioning before attempting these marches. Therefore, a specialised physical training program was implemented in the current investigation to determine whether females could achieve a satisfactory level of combat-related task performance equivalent to infantry soldiers.

2. Method

2.1 Participants

Initially, 78 soldiers were recruited for the trial and assessed for Vo_{2max} and upper and lower body strength. However, only 62 soldiers completed the first CFA trial in August with the others withdrawing due to work commitments, medical and family reasons. Following the 12-week physical training program, only 30 soldiers remained due to a high incidence of deployment. The unit breakdown of soldiers can be found in Annex A.

2.2 Protocol

A detailed protocol of the 4-month study can be found in Annex B.

i) Initially soldiers had various components of their physical fitness assessed, including muscular strength and endurance, anaerobic and aerobic capacities and body composition (see Annex C for detail). These assessments were conducted to establish the physiological status of the soldiers, to ascertain any physical training induced improvements and to determine if any of these basic measures could predict CFA performance. Prior to conducting the initial CFA, soldiers were familiarised with the modified-RDJ course, the WTSS protocol and participated in a 3-week physical conditioning program.

ii) Soldiers carried approximately 27.5 kg in their webbing and pack during the 15-km march with a further 7 kg being carried in the form of weapon and clothing. Upon arrival at the CFA start-point, the soldier's body mass was determined and a cognitive test battery was administered. Immediately prior to commencing the march, soldiers performed a shoot at the WTSS facility. Three 5-km laps were performed such that physiological and psychophysical variables could be monitored. At the completion of the 15-km, soldiers dropped their pack and walked a further 450 m to the modified-RDJ and negotiated the course. After completing the

modified-RDJ, soldiers walked back to the WTSS facility and performed the shoot. The cognitive test battery and mass determination were performed again after WTSS completion. Soldiers started the 15-km march between 0600 and 0820, being staggered by 5 min intervals, and finishing between 0840 and 1140. Approximately 21 soldiers attempted the 15-km march on each of the three testing days.

iii) After the initial CFA, soldiers were broken into two groups, being the specialised physical training and Control groups. The specialised physical training group (STG) was further broken into two groups. Those soldiers that possessed low aerobic fitness were assigned to the group that focused on improving aerobic capacity, whereas those that possessed low muscular strength were assigned to the group that focused on improving muscular strength. Assignment to groups was based on Vo_{2max} and upper and lower body strength. The specialised physical training consisted of three 1-hr sessions per week for 12 weeks (see Annex D for details). The Control group continued to participate in their regular physical training (PT) program.

iv) The physical fitness assessments and CFA were repeated following the specialised physical training program. Those soldiers in the Control group replicated the three-week pre-conditioning training, which was administered in August.

v) In the second CFA, three females and three males from the STG were not included in combat–related assessment comparisons due to injury and illness. Similarly, two males from the Control group were not included (for details see Annex A). This loss of soldiers resulted in altered group sizes for the combat–related assessments; subsequently comparisons can only be made for 8 females (2 Control and 6 STG) and 13 males (4 Control and 9 STG). However, within these groups a further 2 STG soldiers (1 male and 1 female) were removed from RDJ comparisons, due to shoulder injuries. Considering these small sample sizes, limited statistical comparisons were possible and most findings from the second CFA are somewhat descriptive.

2.3 Procedures

Detailed protocols for all testing procedures can be found in Annex C.

i) Prior to the CFA, generic physiological assessments were conducted, which included measures of muscular strength and endurance, aerobic and anaerobic capacity and body composition.

ii) Soldiers were instructed to complete the 15-km march in 165 min, although a 5-min buffer was permitted such that the pass time was set at 170 min. Marching pace was monitored using a personal stopwatch and witches hats positioned every 0.5 km. It was emphasised that the 15-km march was not a performance test, but rather the proceeding RDJ and WTSS would be used as performance discriminators. Soldiers were encouraged to continue and complete the march even if they fell behind the required pace.

iii) A modified-RDJ course was used in this experiment, differing from the regular course in that the wall was 1.5 m high, the pit was reversed such that the soldiers ran down to the bottom and climbed out, a bar was added just prior to the turn around point that required the soldiers to drop to the ground (Figure 1). These modifications resulted in the course being 5 m longer. In addition, a flat wooden wall (no half logs included) was constructed. Consequently, there was no leverage points to aid in scaling the wall. The lower flat wall is a more realistic representation of urban terrain. The reduction in wall height and reversing of the pit were designed to reduce the injury risk, whereas the go-to-ground bar was to simulate a fire and movement activity that was not previously included in the RDJ. The webbing mass carried for both males and females was 10.4 ± 0.8 kg and 9.9 ± 0.4 kg, respectively.

Figure 1. The modified wall, pit and added go-to-ground bar of the RDJ course

iv) Soldiers performed a marksmanship task prior to and following the RDJ/pack-loaded march. WTSS performance was assessed by the firing spread of 4 x 5 rounds at a single target in the standing and prone postures.

v) Core temperature was measured in the gastro-intestinal tract using a non-degradable pill sensor. Heart rate was measured using a chest strap and recording wristwatch. Sweating rate was determined from body mass loss across the work period. Metabolic rate was measured from a portable respiratory gas analysis system on 14 soldiers at the 10 km mark during the march (Figure 2).

Figure 2. Measurement of oxygen consumption using a portable metabolic system

vi) Perceived effort of work, body temperature and thermal comfort were recorded at 5-km intervals using standard scales. Profile of mood states (POMS) and a psychometric test battery (Thinkfast®) were administered ~15 min prior to the march and ~30 min following the march.

2.4 Statistical Comparisons

Due to small group sizes following the physical training, statistical comparisons are limited with mainly descriptive statistics being presented. Subsequently, paired and unpaired *t*-tests were employed to determine differences between groups. Probability level ($P < 0.05$) was not adjusted for the multiple comparisons and needs to be considered when reviewing the findings.

3. Results & Discussion

3.1 Gender Differences for Physiological and Combat-Related Assessments in August

3.1.1 Generic Physical Fitness Assessments

On average, females exhibited lower levels of muscular strength and endurance, and aerobic and anaerobic capacities than males. These differences were still evident after body mass was taken into account (see Annex E Table E1; $P < 0.05$) signifying that the smaller female stature did not account for the lower levels of physical capacities and power. Females exhibited greater Sit-and-Reach scores and skin-fold thickness ($P < 0.05$) than

males, which confirmed the previously accepted evidence that, on average, females possess greater levels of flexibility and body fatness. These findings concur with the wider published literature, such that the differences between the male and female groups were comparable to general population trends.

3.1.2 15-km March Performance

Most males (91%) completed the 15-km march within the time limit (170 min), except for two males who misjudged their speeds (174 & 178 min; Figure 3) and one male who stopped after 10 km complaining of blisters, foot soreness and general fatigue. Conversely, most females (64%) did not complete the march within the specified time with four females failing to complete more than 9 km due to severe pain in the back, shoulders, calves and feet.

The reduced female success rate could be attributed to the greater physiological and psychophysical strain. The body core temperature elevation was greater in the successful females than the males and the unsuccessful females (38.6°C vs. 38.2°C; P=0.07). This indicates that the females' heat dissipation was less than the males and the unsuccessful females were working at a lower heat production rate as confirmed by the slower marching speed. The successful females' perceived thermal status was not different to the males' (warm), although the unsuccessful females perceived themselves to be uncomfortably hot even though they were cooler (P=0.09).

Similarly, the females' heart rate response was exacerbated compared to the males' (163 vs. 154 beats/min; P=0.05). Furthermore, females perceived the physical exertion to be greater than the males (somewhat hard vs. hard; P=0.04), with the unsuccessful females response being further exacerbated (very hard; P=0.04). Considering that the unsuccessful females perceived the work to be harder, yet their cardiovascular strain was equivalent, and they felt hotter, yet they were actually cooler, may imply that these unsuccessful females were less familiar with prolonged vigorous physical activity. This may imply that their PT program is not sufficient for this particular assessment exercise when carrying 35 kg.

Female soldiers who passed the 15-km march in the required time were taller, heavier and stronger, and had slightly greater absolute aerobic capacities than their unsuccessful counterparts (see Annex E Table E2). Furthermore, female soldiers that failed were required to work at a greater percentage of their maximal capacity when walking at 5.5 km/hr (64% vs. 58% Vo_{2max}) compared to the soldiers that passed. Therefore, because of the inappropriate physical characteristics of these soldiers combined with the demands of this task, there was an uneven fail bias that disadvantaged the majority of female soldiers.

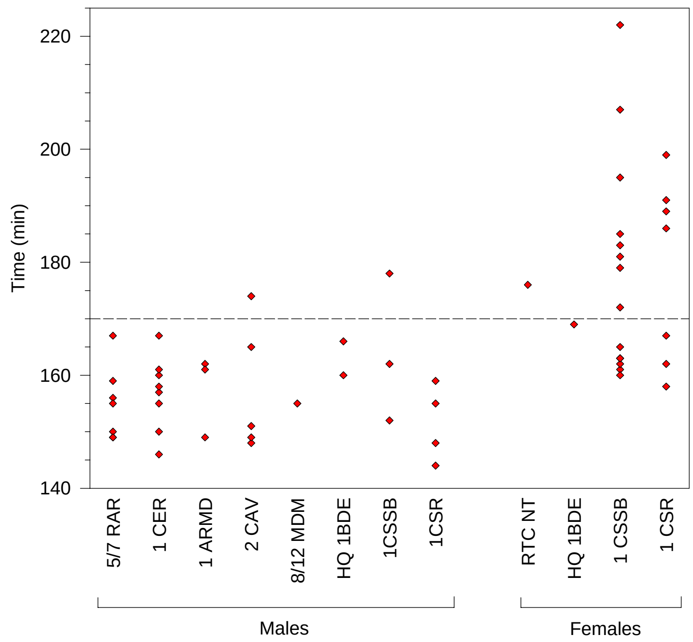

Figure 3. 15-km times for males and females across units, with the pass line being at 170 min

Each soldier's relative work intensity was calculated by dividing the required energy expenditure to carry 35 kg over 15 km at 5.5 km/h on a dirt road with no gradient by their Vo_{2max}. On average, males were required to work at 47.5 ± 4.5% Vo_{2max}, while the female requirement was considerably harder at 61.3 ± 5.9% Vo_{2max}. Separating those that passed and failed, a similar trend emerged; 49.8 ± 6.5% Vo_{2max} for those that passed and 61.4 ± 6.9% Vo_{2max} for those that failed. More discrete analysis found that only 16% of all soldiers that were required to work above 57% Vo_{2max} completed the 15-km march in 165 min. Furthermore, no soldier that was required to work above 66% Vo_{2max} completed the 15-km march in 165 min. Alternatively, 90% of soldiers that were required to work below 55% Vo_{2max} completed the 15-km march in 165 min.

Typically, moderately physically-trained individuals can work at 40% Vo_{2max} for most of the day, 50% Vo_{2max} for about 3 hr, 60% Vo_{2max} for 2 hr and 70% Vo_{2max} for approximately 1 hr. Therefore, those working at >60% Vo_{2max} would find it difficult to sustain this energy expenditure for 3 hr, would be at a greater risk of suffering from an injury/illness and would have limited physical capabilities at the end of the 15-km as a result of the exacerbated physical/physiological strain. Furthermore, when carrying heavy masses, a drift in energy expenditure has been reported (Patton et al., 1991), such that by the third hour an individual that commenced work at 65% Vo_{2max} will be working at approximately 75% Vo_{2max}, which may only be maintainable for about 1 hr when no previous work has been performed. Therefore, a soldier commencing the 15-km march at an intensity greater

than 65% Vo_{2max} will need to be in the class of an elite endurance athlete to have any chance of passing in the required time frame, and even then they still may not successfully complete the 15 km.

Previous gender comparisons from the US Army reported that when soldiers were advised to complete a 10-km march as fast as possible carrying 36 kg, females walked at 4.4 km/hr compared to 5.6 km/hr for males (Harper et al., 1997). This finding is likely to be associated with the reduced absolute aerobic capacity of the female population since it has been reported that males and females walk at similar relative work intensities (45% Vo_{2max}) when the march activity is self-paced (Evans et al., 1980). Therefore, for females to walk at the same speeds as males, they need to possess equivalent absolute aerobic capacities.

The ADF currently uses the 2.4 km run as an estimate of aerobic fitness and while this is an accepted measure of a person's Vo_{2max} expressed relative to body mass it is potentially a poor predictor of 15-km march success. For example, when comparing two individuals with the same relative Vo_{2max} (40 ml/kg/min), they completed the 2.4 km run in the same time and/or perform equally on the multistage fitness assessment, but due to their different body masses (55 kg and 80 kg), the 80 kg individual has an absolute Vo_{2max} of 3.2 l/min, whereas the 55 kg is 2.2 l/min. To complete the CFA while carrying 35 kg, the 55 kg individual needs to work at 1.48 l/min, whereas the 80 kg individual works at 1.78 l/min. Therefore, the 80 kg individual would be required to work at 56% Vo_{2max} (divide 1.78 by 3.20), whereas the 55 kg would be at 67% Vo_{2max} (divide 1.48 by 2.20). Furthermore, the 55 kg individual would need to improve their Vo_{2max} by 20% (48 ml/kg/min or 2.64 l/min) to work at the same relative work intensity as the 80 kg individual. Similarly, Table 1 provides a guide for the required 2.4-km run time for a given body mass at a work intensity of 45% Vo_{2max}, assuming 35 kg is carried at 5.5 km/hr on a flat dirt road. Subsequently, a small soldier needs to possess a far superior level of aerobic fitness relative to their body mass. Further discussion of this body mass issue and other issues related to the current CFA policy are contained in Annex G.

Table 1. The required 2.4-km run time and maximum aerobic capacity (Vo_{2max}) for a soldier to be working at 45% Vo_{2max} when carrying 35 kg at 5.5 km/hr

Soldier's Body Mass (kg)	2.4 km Run Time (min:sec)	Multistage Fitness Test (Level.Shuttle)	Vo_{2max} (ml/kg/min)
50	8:10	14.10	63.5
60	9:10	12.10	56.7
70	9:50	11.8	52.4
80	10:20	10.8	49.6
90	10:50	10.2	47.5
100	11:15	9.7	45.9

While the lower aerobic capacities of the females would have been a major contributor to the poor march success, the lesser leg strength exhibited by the females would have also contributed to the high failure rate in the female group. Mello et al. (1988) reported that

march performance over 8-12 km was mildly correlated (23-40%) with hamstring and quadricep strength and endurance. Therefore, not only does a soldier require an adequate aerobic capacity but also leg muscular strength and endurance, which are important for prolonged load carriage tasks. Based on these findings, it is recommended that leg strength development should be factored into the physical training program.

There is also some suggestion that shoulder breadth also contributes to successful load carriage performance (Harper et al., 1997). This could be attributed to a wider shoulder girdle permitting a better-fitting pack and greater load distribution. Alternatively, the wider shoulder breadth may imply that the individual possesses a greater stature and can absorb the load with smaller increases in energy demands compared to the smaller-framed soldier.

3.1.3 RDJ Performance

3.1.3.1 Baseline

While all males completed the modified RDJ with weapon and webbing within 67 sec (Figure 4), most females (57%) could not complete the RDJ with weapon and webbing due to difficulties negotiating the wall (for more detailed results see Annex E). The females that completed the RDJ with weapon and webbing were on average 34 sec slower than the males, although there was some overlap between the genders with the fastest females bettering the time of three non-combat corps males.

This poor pass rate for female soldiers was most likely influenced by the nature of the modifications to the RDJ course and the webbing mass being standardised to 10 kg, which was viewed by the soldiers as being considerably more than the typical mass carried. Females are usually required to negotiate a 1.5 m wall; however, the vertical surface of the modified-RDJ wall was flat and provided no leverage points, which are present on the typical log walls.

When examining the height of the females that passed and failed the RDJ, no female that was shorter than 163 cm could successfully complete the modified-RDJ. Shorter females accounted for 47% of all the females that could not complete the RDJ. However, no other physical-physiological attribute displayed a difference between the pass-fail groups, except for grip strength (see Annex E Table E3). The relevance of the grip strength between group difference is uncertain, considering that measures of upper and lower body strength did not differ between the pass and fail groups. Potentially, grip strength may give some indication of the overall or residual strength of the individual. Although it also needs to be considered that height was far more important than grip strength when accounting for RDJ success, it is possible for shorter females to negotiate the wall given adequate strength/power and technique training. However, the time necessary to achieve this outcome would be varied and needs to be considered.

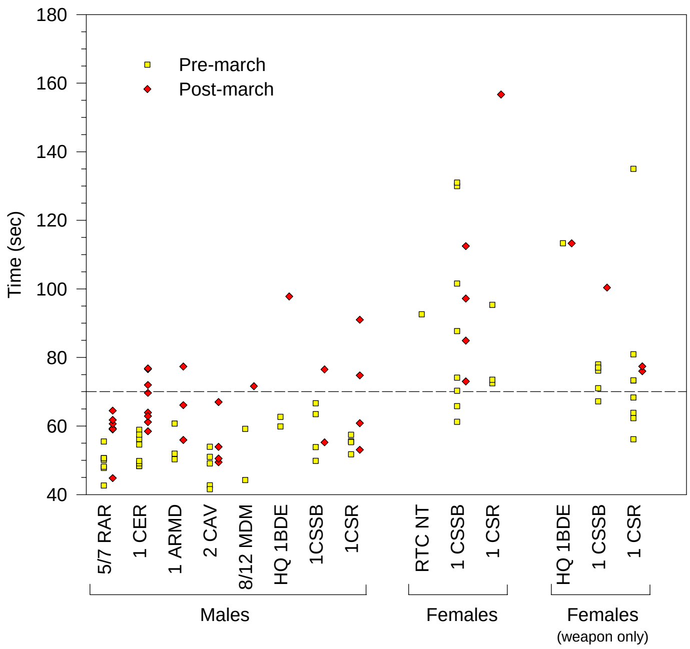

Figure 4. RDJ times for males and females across units. Post-march data is presented only for those soldiers that completed the march in the required time

3.1.3.2 Post 15-km March

Most males (88%) completed the RDJ after successfully finishing the 15-km march with their time being increased by ~13 sec or 24%. Only five females (18%) could complete the RDJ with weapon and webbing after finishing the march in the required time, with an average time decrement of ~20 sec or 24%. While the males generally outperformed the females in the post-march RDJ, the fastest female completed the RDJ in 73 sec, which bettered seven males (Figure 4).

If soldiers from 5/7 Royal Australian Regiment are presumed to set the standard required to perform this infantry-based task of a 15-km march followed by an RDJ, the time to complete the post-march RDJ should be <70 sec. Subsequently, 19 of the 24 males (79%) from combat units and 3 of 10 males (30%) from non-combat units performed this task satisfactorily. Evidently, based on this criterion, no female performed this infantry-based task successfully, although one female approached this barrier (73 sec). This 70-sec barrier was not operationally dictated, but rather based on the abilities of the assessed infantry soldiers. Currently, the RDJ barrier is 50 sec for those soldiers under 41 yr and 70 sec for those over 41 yr, however, the modified-RDJ employed in the current study is longer, has a go-to-ground obstacle and a modified-pit, which subsequently takes more time to negotiate. An operational task analysis needs to be performed to more adequately determine the cut-off time for the modified RDJ, which could be faster or slower than the 70-sec mark.

Overall the males' superior upper/lower body strength and height allowed them to negotiate the wall and other RDJ obstacles with increased efficiency. Furthermore, the males' superior aerobic capacities permitted them to work at a lower intensity during the 15-km march, consequently using fewer carbohydrates and inducing less physiological strain and muscular fatigue. Subsequently, their fresher physiological state and greater carbohydrate availability at the end of the 15-km resulted in a faster RDJ completion time.

3.2 Gender Differences for Physiological and Combat-Related Assessments in November

3.2.1 Generic Physical Fitness Assessments

While the specialised physical training group was split into strength and aerobic groups, between-group analysis was not performed due to the large drop in soldier numbers. Subsequently, comparisons were made between Control and specialised physical training groups.

The specialised physical training induced similar strength gains (~15%) in both males and females for the leg and bench press (see Annex F Table F1). However, aerobic capacity was only improved in the female group (9%). There were trends for both Control and STG males for an improved aerobic capacity (~5%); however, significance was not reached (P = 0.08 and 0.05 respectively). Similarly, the specialised physical training females exhibited a trend for a greater anaerobic capacity (P = 0.05). No improvements were noted for the other physiological assessments. These findings are likely a reflection of the nature of the physical training program and the prevailing physical status of the soldiers. The physical training program (see Annex D) concentrated on strength gains with little aerobic training even for the aerobic group. The weight room was predominantly used, which is not usually employed for PT sessions; therefore, it was not surprising that large strength gains occurred. PT instructors need to consider how more strength activities can be implemented to large group PT sessions without specialist equipment. Furthermore, considering the aerobic capacity gains of the female specialised training group, the aerobic components of the current PT structure for females requires reviewing.

The similar relative strength gain for both males and females is in agreement with the literature, i.e. females tend to exhibit the same relative benefits from physical training compared to males (Cureton et al., 1988; Lemmer et al., 2000). Furthermore, others have reported greater gains in females (Knapik et al., 1980) as was observed in the current investigation for aerobic capacity with this being attributed to females possessing lower initial physical fitness levels (Knapik et al., 1980).

The comparable slight gains in aerobic capacity of both the Control and STG males would imply that the specialised program was no more effective than the standard PT in improving aerobic capacity. The slight increase in aerobic capacity during the 12-week training period could reflect a de-trained state for all soldiers as a result of a major Operational Exercise (Tandem Thrust) and associated leave that occurred in the month preceding the initial assessments. Anecdotally, it is reported that physical fitness is usually

compromised and decreases during these operational exercises due to the nature of the field activities and the lack of regular PT sessions. Little data has been presented relating to this issue of de-training during prolonged operations in soldiers, although US Navy SEALS have exhibited significant reductions in aerobic performance (7% reduction in distance covered in 12-min run) following a 33-day submarine deployment (Fothergill and Sims, 2000).

3.2.2 15-km March

For the Control females (n=2), one female passed as per the August CFA, whereas the other could only complete 10 km in the November CFA at an average speed of 4.3 km/h (lap 1 = 5.2 km/hr; lap 2 = 3.8 km/h). In contrast, this female had finished the 15 km in 206 min (4.4 km/hr; lap 1 = 5.4 km/hr; lap 2 = 4.5 km/hr; lap 3 = 3.8 km/hr) in August (Figure 3). This diminished performance seems attributable to the elevated environmental heat stress. The STG females (n=6) did not improve their CFA (15 km) pass rate with a decrement in pass rate being observed. In August, three females passed (50%), whereas in November only two passed (33%). The female that failed in November was within the prescribed time at 10 km, however, she slowed in the last 5 km reducing her marching speed to 3.9 km/hr in the last lap. The four females that failed to complete the march in 165 min, both pre- and post-physical training, reduced their marching speed by 7% between August and November (5.2 to 4.8 km/hr).

Overall, the male soldiers' pass rate was diminished in the November CFA (100% vs. 77%). All Control males (n=4) passed in both August and November. For the STG males (n=9), only 6 passed in November. One solider became hyperthermic (39.5°C) at 10 km and rested for ~15 min before recommencing the march, finishing in a time of 216 min. However, the 15 min rest was not the cause of the fail since this particular soldier could not maintain the required marching speed in the first 10 km. A second solider completed in a time of 178 min, 30 min slower than in August. The third soldier stopped at the 10-km mark complaining of neck pain from the pack; however, this was the same pack he had used in August.

While muscular strength and aerobic capacity improvements were noted, march performance was somewhat diminished for both males and females. These differences are a reflection that i) the physiological improvements were not sufficient to improve march performance; ii) muscular strength and aerobic capacity, are not related to march success; and/or iii) the exacerbated environmental heat stress levels experienced in the November trial overshadowed any physiological improvements. It is believed that the greater environmental heat stress was the major contributor to the diminished 15 km march success. The greater heart rate induced by the elevated heat dissipation mechanisms and the associated greater psycho-physiological strain would have been a major contributor to the slower marching speed.

3.2.3 RDJ Performance

3.2.3.1 Baseline

In general, including those who could complete the RDJ with weapon and webbing, most females, regardless of group, improved their RDJ times (-16.1 ± 23.6 sec; range: +21.4 to -61 sec). Furthermore, one female who could not complete the RDJ with weapon and webbing in August was able to achieve this in November. Two females exhibited slower RDJ times in November, however, it likely that repeated unsuccessful attempts at completing the RDJ with weapon and webbing induced muscular fatigue.

Control males seemed to improve their performance time (Table 2; P =0.07), although this did not reach significance even though 5 of the 6 soldiers exhibited improved times. STG males (n=12) did exhibit a significant improvement in baseline RDJ performance (Table 2; P<0.001) with all males improving.

This general trend of improved RDJ times in both the STG and Control group likely reflects a learning effect of the modified RDJ course. Although a familiarisation session was implemented prior to the first assessment in August and there was a three-month period between the first and last assessments, some soldiers indicated they felt more comfortable on the course in November and knew how far they could push without injuring themselves. Alternatively, in August, after Tandem Thrust, soldiers were somewhat de-trained and subsequently the reintroduction of the regular PT program improved their physical fitness. Furthermore, definitive support for the STG program over the regular PT program cannot be provided due to the large drop in soldier numbers.

Table 2. Baseline RDJ performance times (sec) for males and females in the Control and specialised physical training groups that could complete the course with weapon and webbing, before and after the physical training period

		August	November
Males	Control (n=6)	53.5 ± 7.6	49.1 ± 3.7
	STG (n=12)	52.4 ± 5.8	48.7 ± 5.8*
Females	Control (n=2)	72.2 ± 2.7	67.0 ± 12.6
	STG (n=6)	90.5 ± 25.5	66.8 ± 9.8*

Values are means ±SD. * Difference between August and November ($P < 0.05$).

3.2.3.2 Post 15-km March

One Control female improved her post-CFA times by ~8 sec, whereas the other female could only complete 10 km of the march in November. Previously, the unsuccessful female had completed the 15-km march in August. Therefore, it is difficult to make comparisons between the August and November assessments for the Control female group. The STG females generally improved (80%; n=5) with the two females that completed the march in 165 min improving their RDJ times by 11.1 and 58.6 sec (Table 3). Similarly, one female could now complete the RDJ following specialised physical training in DPCU, which was not possible in August, while another female could complete the RDJ with webbing and weapon in a similar time to that performed in August when only the weapon was carried.

However, the fifth female took nearly twice as long to complete the RDJ in November (75.4 vs. 141.7 sec).

Control males (n=4) performance time seemed unaltered. Three exhibited improvements (1-5 sec), while the fourth soldier presented a considerably slower time (20 sec). Similarly, the STG males (n=5) exhibited an overall unaltered RDJ performance time with three performing worse (3-13 sec) whereas two improved (3-16 sec).

Table 3. RDJ performance times (sec) following the 15-km march for those completing the march in under 165 min

		August	November
Males	Control (n=4)	64.2 ± 8.0	62.5 ± 11.1
	STG (n=5)	63.0 ± 10.3	63.4 ± 12.5
Females	Control (n=1)	73.0	65.3
	STG (n=2)	120.8 ± 50.8	86.0 ± 17.2

Values are means ±SD

3.2.4 Summary

While the current specialised physical training program was no more effective in improving combat-related task performance than the regular PT program, anecdotally, those individuals that partake in regular physical training outside the work place, i.e. in addition to routine Army PT, exhibited the greatest performance in the combat-related tasks. The typical three PT sessions per week may not be sufficiently effective for inducing physiological benefits with respect to the physical training structure or frequency. While three sessions of physical training per week could be beneficial for sedentary or low-fitness individuals, as the soldiers become accustomed to the exercise and improve their fitness, more sessions are most likely required to facilitate further improvements. Typically, three sessions of physical training per week are recommended to maintain an existing physical fitness: however, to develop physical fitness typically five sessions per week are required. Harman et al. (1997) reported a 13% improvement in aerobic capacity and 17% improvement in leg power in female volunteers when a physical training program was administered five sessions per week over a 14-week period. These improvements translated to occupational task improvements such that the single lift mass was increased by 20%, repetitive lifting capacity by 29% and time taken to complete a 3.6-km pack march with 34 kg load reduced by 19%. Furthermore, after 14 weeks of physical training, ~60% of the females could meet the 'very heavy' job criterion for the US Army compared to 24% prior to the program.

Improvements in muscular strength/endurance do not always translate to enhanced occupational performance. Soldiers administered creatine over a 5-day period exhibited improvements in repetitive bench press performance; however, obstacle course time was unaltered (Warber et al., 2002). The small improvement in muscular strength/endurance conducted in a relatively closed environment seemed masked during the less reproducible multifaceted obstacle course task. The multifaceted obstacle course requires contribution

from muscular strength/endurance, anaerobic and aerobic parameters of various muscle groups combined with motor skill/coordination and agility. Therefore, many factors can affect the resulting time. While muscular endurance of the upper body may be an important factor in contributing to obstacle course performance, the small improvement in repetitive bench press performance was not sufficient to conclusively affect the obstacle course time.

The strength gains exhibited by the STG males and females are clearly related to the implemented program; therefore, an all-corps implementation may be worth investigating. These strength gains may aid in improving other trade-specific tasks, such as single and repetitive lifting, that were not assessed in the current project. A thorough all-corps trade task analysis is required to ascertain the appropriateness of muscular strength for specific trades. However, the large strength gains seemed to be either masked by the elevated environmental heat stress or are not related to CFA success. The improved aerobic capacity of the STG females would indicate that this specialised program was more effective than the currently employed physical training; however, due to the limited soldier numbers, this is not conclusive. It is likely that if soldier numbers were maintained and the CFA was conducted in cooler conditions, the STG females would have exhibited greater improvements than their Control counterparts.

There were some positive aspects of the specialised physical training. In August one female that was only able to complete the RDJ with a weapon was able to complete the RDJ with both weapon and webbing in November. This particular female could negotiate the first wall in August, but failed to negotiate the wall on the return run. Therefore, an improved leg muscular endurance probably diminished the muscular fatigue presented when scaling the wall on the return run, subsequently allowing the soldier to reach a sufficient velocity to propel her over the wall. Another female that could not complete the RDJ at the end of the 15 km without weapon and webbing could do so in November. Two other females also improved their post 15-km march RDJ times. However, these RDJ performance improvements were not sufficient for these female soldiers to successfully complete the RDJ in the proposed infantry-based barrier-time. For the male soldiers, only one improved his performance substantially, now being able to complete the proposed infantry requirements in November compared to being unsuccessful in August.

While there was a large drop in female soldier numbers in the November assessment, the three females that displayed the greatest physical capabilities in August were reassessed in November (1 Control and 2 STG). Therefore, considering that second- and third-rated females still could not achieve the 70-sec barrier although the second female was within 3 sec, it could be assumed that the other females not assessed in November would not have sufficiently improved their combat-related performance to meet the proposed 70-sec barrier. Therefore, at most, only 7% (2 from 28) of the assessed females would be expected to pass this proposed infantry barrier after the 12 weeks of specialised physical training. Individual characteristics such as height, body mass and absolute Vo_{2max} can provide some indication of the potential for soldiers to pass the proposed infantry barrier (see Annex G). Furthermore, the females that still could not negotiate the RDJ wall in November are

mostly limited by their height and technique with further physical training unlikely to result in success. Similarly, the maximal aerobic capacity improvements needed to diminish the relative workload to less than 55% when carrying 35 kg and progressing at 5.5 km/hr, is potentially unattainable for some individuals. For example a 55 kg soldier with a Vo_{2max} of 40 ml/kg/min needs to improve this measure by 20% to work at 56% Vo_{2max}. This 20% improvement is potentially at the upper limit of the achievable gains for Vo_{2max}.

3.3 Environmental Conditions, Physiological Strain and Psychomotor Performance

3.3.1 Environmental Conditions

The environmental conditions varied considerably between the two CFA assessments. In November both dry-bulb and wet-bulb globe temperatures (WBGT) were on average 7°C warmer (Table 4). According to SAFETYMAN work-rest tables for these particular environmental conditions combined with heavy work (>500 Watts), the conditions in August allowed unlimited continuous work to be conducted. However, in November only 45 min of work per hour is recommended at a WBGT of 26°C when working for 5 hours. For the first lap (25°C) 55 min of work per hour is advised, whereas for the last lap (27.9°C) 30 min of work per hour is recommended. The US and Canadian tables offer slightly different cycle durations. At 26.7°C the US recommendation is 25 min work in one hour and only 61 min of continuous work. The corresponding Canadian tables advise 30 min of work per hour and a continuous work time of 95 min for a dry bulb of 29°C and a relative humidity >45%. Therefore, if these practises were adhered to no soldier would pass the CFA, since the rest periods would require the soldiers to move at 11 km/hr in the 30-min work period. These predictions are based on body core temperature reaching 39°C resulting in light heat causalities (5%).

Table 4. Mean environmental conditions during the CFA assessments in August and November

	August			November		
	Dry Bulb (°C)	Relative Humidity (%)	WBGT (°C)	Dry Bulb (°C)	Relative Humidity (%)	WBGT (°C)
Overall	22.7	----------	19.0	28.8	75	26.2
Lap 1	19.5	----------	16.7	26.6	90	24.6
Lap 2	20.7	----------	17.7	28.7	75	26.1
Lap 3	25.5	----------	21.0	31.3	59	28.1

3.3.2 Thermal Strain

In August the incidence of hyperthermia was low, such that a mean body core temperature of 38.3°C was recorded at the end of the march with only 6% of soldiers finishing in excess of 39°C. Whereas, in November the resulting thermal strain was high with one third of all soldiers finishing in excess of 39°C. The mean body core temperature (n=23) at 15 km was 38.8°C with one male reaching a body core temperature of 39.5°C

after 10 km. Between-groups analysis revealed that body core temperatures observed at the end of the 15-km march in November (38.8 ± 0.5°C; n= 49) and August (38.3 ± 0.5°C; n=23) were different (P <0.001). While no soldier required medical treatment for a heat-related illness/injury in November the drop in 15-km success and the tendency for a greater reduction in post 15-km RDJ times (31 ± 22% vs. 26 ± 30%) may imply reduced capability.

As has been suggested by Cotter et al. (2000), the CFA completion time should be indexed to environmental heat stress, i.e. when WBGT exceeds 26°C then rest periods or a slower marching pace should be implemented. Similarly, as seems to be the current practice for regiments in Northern Australia, the CFA should be conducted early in the morning in the cooler months provided that the main objective of the assessment is to carry the appropriate load mass over 15 km in 165 min.

3.3.3 Cardiovascular Strain

In November soldiers that completed the 15-km march exhibited a mean heart rate (HR) of 155 ± 12 beats/min (n=20; 82 ± 5% maximum HR; HR_{max}) over the duration of the march. This mean HR was greater than that exhibited in the August trial for the same soldiers (150 ± 14 beats/min; P = 0.02). This difference was more pronounced in the last 5-km lap (~10 beats/min) for those soldiers that passed in both August and November (n=13). The HR augmentation in November seemed equivalent between the specialised physical training and Control groups and is concomitant with the well-documented elevation in warmer environments, due to the greater skin blood flow demand for cooling.

The following points highlight some extreme examples of cardiovascular strain observed in individual soldiers. Two females exhibiting HR in excess of 88% HR_{max} (174-189 beats/min) for ~2 hr, which is quite excessive in non-competitive athletes:

- One female exhibited a mean HR of 189 beats/min (93% HR_{max}) during the first lap; however, her marching pace was under that required to successfully complete the CFA (5.3 km/hr). In the second lap, her pace dropped (3.8 km/hr) as did her HR (177 beats/min; 88% HR_{max}). Consequentially, the combination of the high HR at a slow marching speed resulted in only 10 km being completed.
- Another female worked at 174 beats/min (91% HR_{max}) and 181 beats/min (95% HR_{max}) in the first and second laps respectively. While marching speed was sufficient in the first 10 km (5.7 km/hr), thereafter her pace dropped considerably (4.0 km/hr), although HR was still at 168 beats/min (88% HR_{max}).

The magnitude of these HR elevations is typical for short-duration physically-demanding activities (<5 min). However, the duration of these HR elevations is extreme. Such high HRs would imply predominately anaerobic work, which relies heavily on carbohydrates and cannot be sustained indefinitely. It is likely that these females depleted their carbohydrate stores and/or the perceived work intensity, induced by the high heart rate, was too great to maintain the sufficient walking pace. While endurance-trained athletes can maintain high work outputs for extended durations, HR elevations >90% HR_{max} for

2–hr periods are not typical, but rather 80-85% HR_{max} are more common. However, it is very unlikely that this degree of HR elevation would be experienced during a typical CFA since these females would be carrying no more than 20 kg.

Many of the soldiers that possessed physical/physiological characteristics that biased them towards CFA failure exhibited tremendous motivation to pass the CFA, which is probably indicative of the Defence culture. While this is a beneficial trait, problems can arise when a soldier pushes past their limits and ignores the physiological warning signs. Overstressing the cardiovascular system has been reported to cause cardiac damage during excessive athletic events lasting from 5-48 hr (Whyte et al., 2000; Shave et al., 2002), although the damage has been reported to be minimal, while some soldiers that worked at excessive HR for 2-3 hr may have suffered minor cardiac damage. Furthermore, soldiers that may have an unknown underlying cardiac condition are of greater concern when their HR becomes elevated. This condition could be congenital or be progressive such that it has worsened over a number of years.

The administration of an arduous task, such as the CFA, without sufficient physical training will result in exacerbated HR elevations, as compared to a fit soldier, due to a number of physiological limitations, including sub-optimal oxygen and energy substrate delivery, cardiac contractility, blood volume deficiencies, etc. Subsequently, the heart will have to work harder to maintain the same absolute work intensity in the less fit soldier. The combination of poor physical training preparation with an unknown prevailing medical condition can place a solider at considerable risk of a serious cardiovascular injury. Furthermore, the HR elevation can be further exacerbated in a warm-to-hot environment by 10-20 beats/min due to the elevated blood flow at the skin as a means to rid the body of heat. Therefore, adequate physical training in appropriate environmental conditions (acclimatisation) is crucial to minimise the potential of serious health implications resulting from high cardiovascular strain.

3.3.4 Psychomotor Performance

There were no significant differences in psychomotor performance between pre- and post-march ($P > 0.05$) in August. That is, the residual fatigue produced by the combination of a 15-km march and a subsequent RDJ and marksmanship tasks did not affect cognitive function. Similarly, in November there was no significant effect between pre- and post-CFA cognitive function assessments. These performance tasks assessed the effects of residual fatigue since there was a considerable time gap between finishing the 15-km march and RDJ before the psychomotor assessments. It is uncertain whether a decrement in psychomotor performance would have been observed if these tasks were completed immediately after the 15-km march. Similarly, more complex and longer duration cognitive tasks could have identified deficiencies.

3.3.5 Mood States

In August there were significant increases in perceived levels of fatigue and distraction ($P < 0.05$) following the 15-km march, RDJ and WTSS tasks independent of gender.

Soldiers tended to also show a decline in levels of happiness, attention, activity and anxiety. Anger and depression increased slightly following the CFA compared to baseline mood states. Similar findings were observed in November.

3.4 WTSS Performance

The 15-km march did not affect marksmanship scores, except for males in the prone position in the August trial (Table 5). The August pre-CFA prone male spread scores were considerably less than those in other groups; subsequently, there was a greater chance of decrement for these soldiers. In November the male prone baseline mean was considerably higher than prone baseline August mean. Closer inspection of data revealed that those male soldiers that participated in both August and November assessments exhibited a 50% increase in baseline prone spread scores in November (124 ± 32 vs. 187 ± 79), while standing scores were unaltered (338 ± 78 vs. 328 ± 78). Furthermore, for those male soldiers that completed both CFA trials, the baseline prone spread score in November was greater than the post-CFA prone spread score in August (187 ± 79 vs. 131 ± 39). The cause of this elevated baseline score in November is uncertain. Additionally, when isolating the soldiers that completed both CFA trials, these males did not exhibit a decrement in prone spread scores after the CFA (124 ± 32 vs. 131 ± 39). It is possible that the higher level of marksmanship contributed to the greater potential for decrement following the 15-km march.

In August males performed better than females in all shoots (standing and prone), pre- and post-15-km march ($P < 0.05$), whereas in November males performed better than females in only the pre-standing shoot ($P < 0.05$).

Table 5. Spread scores for the marksmanship task performed prior to and after the 15-km march in August and November

		August			**November**		
		N	**Pre**	**Post**	**N**	**Pre**	**Post**
Males	**Standing**	32	344 ± 82	354 ± 72	11	320 ± 55	374 ± 97
	Prone	32	118 ± 35	146 ± 52*	11	179 ± 75	183 ± 61
Females	**Standing**	24	448 ± 114	464 ± 71	7	396 ± 65	433 ± 103
	Prone	24	211 ± 112	219 ± 89	7	178 ± 63	202 ± 78

*Difference between Pre and Post ($P < 0.05$)

Knapik et al. (1997) reported unaltered marksmanship ability in soldiers of Special Operation Forces when the shoot was conducted 10 min after marching 20 km while carrying up to 61 kg. However, Knapik et al. (1991) also reported a decrement in marksmanship accuracy in infantry soldiers after a 20-km road march carrying 46 kg in which the marksmanship task was performed within 5 min after the march was completed. These mixed findings may imply that, given sufficient rest, soldiers can maintain marksmanship ability following a load march or that the marksmanship ability of soldiers in Special Operation Forces is not compromised in a fatigued state and/or the level of physical fatigue following the march was less in this group of soldiers.

In August the WTSS task was performed 18.3 ± 6.0 min after the end of the 15-km march and 9.4 ± 3.1 min after the RDJ, whereas in November the WTSS task occurred 31.1 ± 9.8 min after the end of the 15-km march and 18.9 ± 7.8 min after the RDJ. The longer time in November was a result of different personnel operating the WTSS facility and a greater number of technical problems. This delay period between march completion and performing the WTSS task may have contributed to lack of difference in spread scores and would imply that the residual fatigue of the march was being assessed rather than the result of the physiological strain exhibited at the cessation of the march. Unaltered marksmanship ability has also been documented during and following a 72-h sustained infantry operation (Nindl et al., 2002). Similarly, as with the current investigation, residual fatigue was the assessed factor, not acute physiological strain associated with a physically intense activity. In conclusion, a marksmanship task immediately following the 15-km march would seem a highly appropriate assessment for combat soldiers, conveying their overall military performance ability related to physiological, physical and cognitive factors.

3.5 Limitations

The major limitation related to the specialised physical training was the large loss of soldiers in the November trial. This drop in numbers limited any strong conclusions to be drawn with regard to the effectiveness of the physical training program. While a large number of soldiers were recruited to off-set the potential of reduced numbers resulting from injury or drop-out, the magnitude of deployed soldiers between August and November could not have been foreseen or controlled by DSTO and/or 1 Brigade Headquarters and was hence unavoidable despite forward planning.

The other major limitation was the change in environmental conditions between August and November. This factor potentially masked combat-related performance improvements induced by the specialised physical training and may explain the majority of the performance decrements observed in the November assessments. Initially, the project was intended to occur in 2000. However, due to Operation Warden, a 12-month delay was implemented. In 2001, the two CFA trials were planned for May and August. However, Tandem Thrust caused a further delay. An ideal situation would have been to delay the study to 2002.

A further limitation was that soldiers had recently returned from Tandem Thrust and post-exercise leave. Therefore, it is likely, based on anecdotal reports, that their physical fitness was low. All soldiers, including the Control group, would have increased their volume of physical training across the three-month training period relative to their initial assessment in July/August. This issue is evident in the one Control female soldier that passed the proposed infantry-based barrier in the November assessment and commented that her training regimen and perceived physical fitness was superior in November compared with August. Future investigations need to identify when major exercises are programmed such that the project outcomes are not influenced by the prevailing physical fitness status.

As reported, improvements in the baseline RDJ performance could indicate a learning effect. The RDJ course format was different to the regular course in that the wall surface was flat and without the leverage points produced by the half logs in the conventional RDJ. The knee-highs were slightly higher than experienced on the conventional course since grass had not been laid. Following the knee-highs, a go-to-ground bar was added. The broad jump pit was replaced with an inclined pit with soldiers running down and climbing out at the bottom. Soldiers were provided with a familiarisation session three weeks prior to completing the baseline RDJ in August. However, a number of soldiers commented that they approached the RDJ differently in November, i.e. knowing where they could progress at a faster rate without the risk of injury. A reproducibility study was conducted on five soldiers in August with soldiers completing the RDJ once per day on five consecutive days. There did not appear to be a learning effect and the reproducibility was ~4%.

4. Conclusions

i) The majority of males (91%) could complete the 15-km march in 165 min carrying 35 kg, whereas only a minority of females (36%) could achieve this task.
ii) The female soldiers that passed the 15-km march were taller, heavier and possessed greater strength and absolute Vo_{2max} than unsuccessful counterparts. Furthermore, the higher relative exercise intensity required by the females also contributed to the low 15-km march pass rate.
iii) Most females (57%) could not complete the RDJ with weapon and webbing, whereas all males could achieve this task.
iv) Height, strength and technique were likely factors that contributed to the lack of success in the RDJ task for female soldiers.
v) All infantry and most male combat soldiers (79%) passed the proposed infantry-based RDJ barrier time after the 15-km march, whereas no female soldier could achieve this time prior to implementation of the specialised physical training program.
vi) The specialised physical training appeared to provide some physiological and combat-related task performance benefits, although no improvements were observed for the pass rate for both the 15-km march and the proposed infantry-based RDJ barrier time. However, the vastly different environmental conditions between August and November prevented any clear conclusions.
vii) Only one Control female could pass the proposed infantry-based RDJ barrier time in November with her personal physical training regimen contributing to the physical improvement.
viii) The levels of thermal and cardiovascular strain were augmented in November when compared to August. The level of cardiovascular strain approached excessive levels in some of the smaller soldiers.
ix) Past studies and the findings of this trial suggest that the relative work intensity required to complete the 15-km march in 165 min needs to be below 55% Vo_{2max} at the commencement of the march. However, to further reduce undue strain on the soldier

and the potential for injury and to maintain adequate physical capabilities at the end of the 15 km, soldiers should not commence the 15-km march at greater than 50% Vo_{2max}.

x) WTSS performance was diminished post 15-km march only in males in the prone position in August. This potentially implies that those soldiers that possess high marksmanship accuracy are most vulnerable to decrements in WTSS performance as a consequence of residual fatigue induced by the 15-km march and RDJ.

xi) The current CFA is an appropriate assessment for trades that are likely to be involved in prolonged load carriage; however, its relevance to less endurance-demanding trades is uncertain.

xii) Other physical assessments need to be devised to adequately assess a soldier's ability to perform other physically-demanding occupational tasks such as heavy lifting.

5. Recommendations

i) For more definitive recommendations on CFA structure, a trade-task analysis is required for all corps. This will determine the appropriateness of the current format in providing the desired outcomes of the assessment in relation to current occupational tasks that require prolonged load carriage. Furthermore, additional assessments may be necessary for trade-tasks that require heavy lifting.

ii) Consideration should be given to modifying BFA standards for Land Command soldiers such that the aerobic capacity of all soldiers is sufficient to result in a predicted work intensity of less than 50% Vo_{2max} at the commencement of the 15-km march (see Annex G for more detail).

iii) CFA administration should be planned for the cooler, less humid months to diminish the likelihood of thermal injuries, which appears to be the general practice at 1 Brigade.

iv) In operational settings, it is possible that personnel may be required to work in hot, humid conditions. Therefore, a longer completion time (allowing rest periods), reduced distance and lighter loads are possible alterations for both CFA and operations. This would theoretically reduce the potential for thermal injury and increase the physical capabilities of the soldiers at the end of the 15-km march.

v) While it is recommended that a sufficient physical training program be implemented prior to the CFA, this is contrary to the ideal scenario that all soldiers should achieve a minimum standard that can be randomly assessed at any time, i.e. augmentation of the routine physical training program should not be required (see Annex G for more detail).

vi) The inclusion of shooting and RDJ components at the end of the 15-km is recommended for infantry and associated trades. The value of including these activities for all trades requires further investigation.

vii) Prevailing injuries and illnesses need to be critically reviewed prior to conducting a CFA or commencing operations or training. Screening for the early signs of febrile infections, i.e. before resting body core temperature is elevated and/or the individual is aware of the illness, could be beneficial for not only the individual but for the unit as a whole. Prior screening may therefore circumvent any possible decrements in operational effectiveness due to the incapacitation of an individual.

viii) Further consideration is necessary to optimise current physical training structure with respect to general and trade-specific physical fitness. The physical training should not focus on a particular assessment, but rather the critical trade-tasks with the assessment complementing these tasks.

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Annex A: CFA Participants

Table A1. Unit and gender breakdown of soldiers participating in the August and November 15-km march

	August			November		
Unit	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**
1CSSB	4	15	19	2	11	13
1CSR	4	11	15	4	1	5
HQ 1 BDE	2	1	3	-	-	-
RTC NT	-	1	1	-	-	-
1CER	8	-	8	6	-	6
5/7 RAR	7	-	7	-	-	-
1 ARMD	3	-	3	2	-	2
2 CAV	5	-	5	2	-	2
8/12 MDM	1	-	1	2	-	2
Total	**34**	**28**	**62**	**18**	**12**	**30**

Deployment was the greatest factor responsible for the drastic drop in numbers (76%), followed by injury (15%), reposting (3%), training (3%), and AWOL (3%). Two soldiers that did not complete the first CFA in August due to sickness and inability to swallow the radio-pill participated in the November assessment.

A.1. Injury, Illness and Other Factors Affecting CFA Performance

Three STG females were not included in the 15-km march and post-RDJ comparisons:

- Twisted knee just prior to 10-km mark, although this female was maintaining the required marching speed.
- Prevailing sickness (infection) which had not cleared from initial sickness two weeks prior. Soldier was on schedule after 5 km but significantly dropped pace in second 5 km and was vomiting.
- Hip problem during the physical training, which was attributed to changes in her foot structure, i.e. becoming flat-footed. This soldier was on schedule at the 10-km mark, but her marching pace dropped in the last 5 km.

Two males from the Control group were removed from the 15-km march and post-RDJ comparisons:

- One male attempted the march with a borrowed pack and it was evident within the first 5 km that the pack was poorly fitted. With numerous readjustments not helping, this soldier could not maintain the required pace and stopped after 10 km. This particular soldier exhibited the highest Vo_{2max} (58.5 ml/kg/min).
- Second male was vomiting profusely at the end of the march and was unable to complete the march in the required time. It is possible that this soldier was suffering from heat illness, although his body core temperature was only 39.4°C at the end of the march. This level of body temperature elevation is readily observed during similar combinations of exercise and heat stress, and vomiting is extremely uncommon. Furthermore, considering this individual possessed one of the highest Vo_{2max} (57.9 ml/kg/min), it is most likely that an underlying infection was responsible for the

illness and the inability of this soldier to complete the march in the required time period.

Three STG males were also removed from the 15-km march and post-RDJ comparisons:
- A prevailing shoulder injury resulted in one soldier dropping his pack at the 5-km mark. At this point he was within the prescribed time.
- A second soldier twisted his ankle at ~9-km mark. This was a previous injury and the ankle was heavily taped prior to the start of the CFA. At the 10-km mark this soldier was within the prescribed time.
- Cracked ribs, which had occurred ~6 weeks prior to the CFA, severely impeded a third soldier's progress. While he completed the first 5-km at the required rate, his pace dropped in the second 5 km and he did not attempt the third 5-km lap. He also did not attempt the baseline RDJ.

Annex B: Protocol Overview

B.1 Initial Assessments (23rd July - 20th August)

- Soldiers were recruited with aerobic and strength assessments being conducted using the multistage fitness test, and bench and leg press apparatus respectively.
- All participants were familiarised with the modified RDJ course and the WTSS protocol.
- A three-week pre-conditioning period (30th July- 17th August) was implemented to prepare all soldiers for the 15-km march.
- A baseline RDJ performance time was established for each soldier in the week prior to the 15-km march.
- A generic assessment day (20th August) determined a number of physiological parameters, which included body composition, strength, power, muscular endurance and anaerobic capacity measurements.

B.2 CFA Days (21st –23rd August)

- Upon arrival, soldiers' body mass, pack mass and webbing mass was determined. Soldiers carried 8.9 ± 1.6 kg in webbing and 18.6 ± 1.6 kg in their pack (27.5 kg), which did not differ between genders or units.
- Thereafter, a cognitive test battery was administered.
- Immediately prior to commencing the march, soldiers performed a shoot at the WTSS facility.
- Three 5-km laps were performed such that physiological and psychophysical variables could be monitored.
- At the completion of the 15-km, soldiers dropped their packs and walked a further 450 m to the RDJ and negotiated the course.
- After completing the RDJ, soldiers walked back to the WTSS facility and performed the shoot.
- The cognitive test battery and mass determination were again performed after WTSS completion.
- Soldiers started the 15-km march between 0600 and 0820, being staggered by 5 min intervals, and finishing between 0840 and 1140.
- Approximately 21 soldiers attempted the 15-km march on each of the three testing days.

B.3 Specialised Physical Training (27th August – 16th November)

- The week following the CFA soldiers commenced the specialised physical training.
- Two physical training groups were established which concentrated on improving aerobic capacity or strength or a combination of both (see Annex D).
- Assignment to groups was based on Vo_{2max} and upper and lower body strength.
- Training groups reported on Monday, Wednesday and Friday at 0900, 1000 or 1100 for a 1-hr session over a 12-week period.

B.4 Post Physical Training Assessments (29th October – 21st November)

- The initial generic physical fitness assessments and CFA were repeated following the specialised physical training program.
- Those soldiers in the Control group replicated the three-week pre-conditioning training (29th October – 16th November), which was administered in August.
- On CFA days, the 15-km march commenced between 0515 and 0635, with finish times between 0800 and 0953. The earlier start times were employed due to the earlier sunrise.

Annex C: Experimental Procedures

C.1 Generic Physiological Assessments

Multistage Fitness Test
This assessment predicted maximal aerobic capacity by having soldiers run back and forth between markers, which were set 20 m apart. An audio signal dictated the running speed with the speed increasing as the test progressed. Soldiers continued to run until they could no longer maintain the dictated running pace. Peak heart rate was also obtained from a Polar heart rate monitor.

Strength assessments
Bench and leg press apparatus were employed. Soldiers completed as many repetitions as possible with the set mass only allowing a maximum of five repetitions. A predictive equation derived the maximum single-lift mass (1RM).

Hand grip
Soldiers griped a dynamometer to produce a maximal force with three attempts for both hands. This assessment provided an indication of the static muscular strength.

Static lift
Soldiers adopted a squatting posture with knees at 90 ° and pulled on a handle that was fixed to a dynamometer with the maximum force being recorded on three occasions. This assessment provided a measure of static muscular strength of the lower body (legs and lower back).

Pull-ups
This assessment provided a measure of upper body (biceps, latissimus dorsi, trapezius, deltoid, other shoulder and back muscle groups) dynamic muscular endurance. Soldiers completed as many pull-ups as possible.

Push-ups
Soldiers completed as many push-ups as possible at a designated cadence of 1 per second. This assessment also provided a measure of upper body (pectoralis, triceps and deltoid muscle groups) dynamic muscular endurance.

Wingate
Soldiers performed as much work as possible in a 30 sec period, following a 5 min warm-up on a cycle ergometer. From this assessment, the peak power and anaerobic capacity of the lower body were measured.

Flexibility
The best of three Sit-and-Reach assessments was recorded. Soldiers sat on the floor with their legs straight out in front and were required to reach as far as possible towards their toes (or past) with straight legs.

Body Composition
Height, body mass and skin folds (four sites) were measured.

C.2 CFA Assessments

Soldiers were instructed to complete the 15-km march in 165 min. Marching pace could be monitored using a personal stopwatch and witches hats positioned every 0.5 km. It was emphasised that the 15-km march was not a performance test, but rather the proceeding RDJ and WTSS would be used as performance discriminators. Soldiers were encouraged to continue and complete the march, even if they fell behind the required pace.

RDJ
The course used in this experiment differed to the regular course in that the wall was 1.5 m high, the pit was reversed such that the soldiers ran down to the bottom and climbed out, a bar was added just prior to the turn around point, which required the soldiers to drop to the ground. These modifications resulted in the course being 5 m longer and the construction of the wall was a flat wooden surface, not half logs, which provided no leverage points to aid in scaling the wall. A flat wall was used in this instance to represent an urban terrain obstacle. The webbing mass for the males and females was 10.4 ± 0.8 kg and 9.9 ± 0.4 kg, respectively.

WTSS
Soldiers performed a marksmanship task prior to and following the RDJ and pack-loaded march. WTSS performance was assessed by the firing spread of 4 x 5 rounds at a single target in the standing and prone postures. Each soldier did not individually zero the weapon, but rather the WTSS manager applied a common zero with each soldier shooting from the same lane for the pre- and post-assessments.

Physiological Measurements
- Core temperature was measured in the gastro-intestinal tract using non-degradable pill sensors. The pills contain a temperature dependant oscillator transmitting in the radio frequency range. This low-power signal is detected by a portable logger.
- Heart rate was measured at 5-sec intervals using telemetrised recording of the electrical wave of the heart's ventricular depolarisation.
- Sweating rate was determined from body mass loss across the work period, uncorrected for respiratory evaporative water loss. Soldiers' pre- and post-clothing mass was subtracted from their clothed mass.
- Metabolic rate was measured from a portable respiratory gas analysis system on 14 soldiers at the 10 km mark during the march. Three minutes of expired gas was sampled for determination of oxygen consumption.

Psychophysical measures
- Perceived effort of work was recorded at 5-km intervals using a standard, 15-point scale (6-20: 7=very, very light; 15=hard; 19=very, very hard).
- Perceived body temperature and thermal comfort were recorded at 5-km intervals using 13- and 5-point scales, respectively (1-13: 1=unbearably cold, 7=neutral,

10=hot, 13=unbearably hot; 1-5: 1=comfortable, 3=uncomfortable, 5=extremely uncomfortable).

Mood analysis and psychometric assessments

- Profile of mood states (POMS) and a psychometric test battery (Thinkfast®) were administered ~15 min prior to the march and ~30 min following the march.
- In August five individual tasks were performed, which evaluated response time, vigilance and short-term memory. Soldiers were familiarised with these tasks 1-3 days prior to the march.
- Since no decrement in cognitive performance was exhibited in August, two tasks were selected for administration in the November trial. These tasks represented the most challenging tests and were repeated three times prior to and at the end of the 15-km march.

Annex D: Specialised Physical Training Program

The Specialised Physical Training group (STG) were divided into two sub-groups - strength and aerobic groups.

Table D1. Aerobic Group

	Monday	Wednesday	Friday
Week 1	Weight Session #1 (3x10) 20 min Run	20 min Circuit (30-sec) 30 min Run	Weight Session #1 (3x10) 20 min Run
Week 2	Weight Session #1 (3x6) 20 min Run	20 min Circuit (30-sec) 30 min Run	Weight Session #1 (3x6) 20 min Run
Week 3	Weight Session #1 (3x3) 20 min Run	20 min Circuit (45-sec) 30 min Run	Weight Session #1 (3x3) 25 min Pack March
Week 4	Weight Session #1 (3x10) 20 min Run	Box & Skip	Weight Session #1 (3x10) 20 min Run
Week 5	Weight Session #1 (3x3) 20 min Run	20 min Circuit (45-sec) 30 min Run	Weight Session #1 (3x3) 30 min Pack March
Week 6	Weight Session #1 (3x6) 20 min Run	20 min Circuit (60-sec) including Hop/Jump 30 min Run	Water Sport Day
Week 7	Weight Session #1 (3x3) 20 min Run	Box & Skip	Weight Session #1 (3x3) 2 x 5 min HIA 6 x 400 m Intervals
Week 8	Weight Session #1 (3x10) 20 min Run	20 min Circuit (60-sec) including Hop/Jump 30 min Run	3 x 15 min Pack March 2 x 5 min HIA
Week 9	Weight Session #1 (3x3) 20 min Run	10 min Circuit (75-sec) including Hop/Bound/Sprint 40 min Run	Weight Session #1 (3x3) 2 x 5 min HIA Ladder Interval
Week 10	Weight Session #1 (3x6) 20 min Run	Box & Skip	Weight Session #1 (3x6) 30 min Run
Week 11	Weight Session #1 (3x3) 20 min Run	Weight Session #1 (3x3) Hop/Bound/Sprint	3 x 15 min Pack March 2 x 5 min HIA
Week 12	Weight Session #1 (3x3) 20 min Run	10 min Circuit (75-sec) including Hop/Bound/Sprint 30 min Run	Water Sport Day

Table D2. Strength Group

	Monday	Wednesday	Friday
Week 1	Weight Session #2 (3x10)	20 min Circuit (30-sec) 30 min Run	Weight Session #1 (3x10) 20 min Run
Week 2	Weight Session #2 (3x6)	20 min Circuit (30-sec) 30 min Run	Weight Session #1 (3x6) 20 min Run
Week 3	Weight Session #2 (3x3)	20 min Circuit (45-sec) 30 min Run	Weight Session #1 (3x3) 25 min Pack March
Week 4	Weight Session #2 (3x10)	Box & Skip	Weight Session #1 (3x10) 20 min Run
Week 5	Weight Session #2 (3x3)	20 min Circuit (45-sec) 30 min Run	Weight Session #1 (3x3) 30 min Pack March
Week 6	Weight Session #2 (3x6)	20 min Circuit (60-sec) including Hop/Jump 30 min Run	Water Sport Day
Week 7	Weight Session #2 (3x3)	Box & Skip	Weight Session #1 (3x3) 20 min HIA 6 x 400 m Intervals
Week 8	Weight Session #2 (3x10)	20 min Circuit (60-sec) including Hop/Jump 30 min Run	3 x 15 min Pack March 2 x 5 min HIA
Week 9	Weight Session #2 (3x3)	10 min Circuit (75-sec) including Hop/Bound/Sprint 40 min Run	Weight Session #1 (3x3) 20 min HIA Ladder Interval
Week 10	Weight Session #2 (3x6)	Box & Skip	Weight Session #1 (3x6) 30 min Run
Week 11	Weight Session #2 (3x3)	Weight Session #2 (3x3)	3 x 15 min Pack March 2 x 5 min HIA
Week 12	Weight Session #2 (3x3)	10 min Circuit (75-sec) including Hop/Bound/Sprint 30 min Run	Water Sport Day

Weight Sessions

- On the heavier weight days, i.e. 3-6 reps, an additional warm-up set of 8-10 reps at 80-90% 8-10RM was required.
- On the last three sets of the heavier weight days, i.e. 3-6 reps, the exercise should be done to failure with spotters being able to assist with the last 1-2 reps.
- For chins and dips, if a participant was unable to complete a single repetition, the exercise was modified to make it easier as long as progressive overload occurred. The

last set consisted of the eccentric component of the exercise completed by the participant with the spotter assisting the concentric component.
- If the participant was able to complete more than the required number of repetitions then weight was added to the exercise.

Session #1
- Dumbbell deadlift with shrug
- Chins
- Step ups
- Dips

Session #2
- Dumbbell deadlift with shrug
- Chins
- Step ups
- Dips
- Leg Press
- Bench Press

Running Sessions
- Participants ran an out-and-back course trying to run as far as possible for each session, attempting to increase the distance run in a set time period in each session.

Circuit Sessions
- Example activities are listed below.
- The duration of each activity increased as the weeks progressed. Participants were instructed to move rapidly between exercise stations and maintain intensity throughout the circuit.
- Circuit was set up such that exercise order was upper body, core stability and lower body.
- Hopping and bounding exercises were introduced at Week 6 with the sprint component added at Week 9.

Upper Body
- Push ups
- Partner chins
- Partner dips
- Dumbbell front and side raises
- Crab walks
- Circle in push-up position

Core Stability
- Trunk flexion
- Trunk rotation
- Hip Flexion (lower abdominal)

- Medicine ball throws

Lower Body
- Walking lunges
- Body weight squats
- Side squats
- Burpees
- Short sprints

Hopping/Bounding
- Hopping
- Bounding
- Jumps

Box and Skip Sessions
- Boxercise-style classes were constructed by the PTI.

Water Sport Days
- These days were planned as recovery days with activities at the discretion of the PTI.

6 x 400m Interval Sessions
- The intervals were 3 min with the participants instructed to run as fast as possible.

Ladder Interval Sessions
- 3 x (50 m, 75 m, 100 m and 150 m) with jog back recovery and 3 min rest between sets.

2 x 5 min HIA (High Intensity Activity) Sessions
- Five activities were selected from the circuit list with 60 sec spent at each station.

Annex E: Results for August Assessments

E.1 Generic Physical Fitness Assessments

Table E1. Physiological assessments of males (n=35) and females (n=28)

	Males	Females
Leg Press (kg)	139.4 ± 20.4	97.4 ± 22.5*
Leg Press (kg/kg body mass)	1.69 ± 0.24	1.56 ± 0.15*
Bench Press (kg)	117.9 ± 23.5	51.5 ± 12.3*
Bench Press (kg/kg body mass)	1.42 ± 0.23	0.80 ± 0.15*
Vo_{2max} (l/min)	3.88 ± 0.44	2.62 ± 0.37*
Vo_{2max} (ml/kg/min)	47.1 ± 5.2	40.8 ± 3.2*
R. Hand (N)	53.3 ± 7.3	33.9 ± 5.0*
R. Hand (N/kg body mass)	0.65 ± 0.09	0.53 ± 0.06*
L. Hand (N)	52.2 ± 7.4	31.9 ± 4.6*
L. Hand (N/kg body mass)	0.63 ± 0.09	0.49 ± 0.05*
Static Lift (N)	141.5 ± 19.4	80.3 ± 13.9*
Static Lift (N/kg body mass)	1.71 ± 0.21	1.25 ± 0.17*
Peak Power (Watts)	772 ± 70	486 ± 62*
Peak Power (Watts/kg body mass)	9.40 ± 1.22	7.59 ± 0.96*
30-sec Work (kJ)	17.2 ± 1.5	11.3 ± 1.3*
30-sec Work (kJ/kg body mass)	0.21 ± 0.03	0.18 ± 0.02*
Push-ups	42 ± 10	24 ± 7*
Pull-ups	9 ± 4	1 ± 2*
Skin folds (sum of 4; mm)	63.7 ± 26.0	78.0 ± 17.8*
Sit-and-Reach	0.0 ± 9.3	6.6 ± 11.1*

Values are means ±SD. *Difference between males and females ($P < 0.05$)

E.2 15-km March

A direct discriminate function analysis was performed using six physical characteristic variables (height, weight, bench press load, right-hand grip strength and %Vo_{2max}) as predictors of CFA success. These factors were significantly different between the pass and fail groups. Left-hand grip strength and Vo_{2max} were dropped from the analysis because they were highly correlated with right-hand grip strength (pass, r=0.894; fail, r=0.700) and %Vo_{2max} required to successfully complete the CFA (pass, r=-0.900; fail, r=-0.934), respectively.

Discriminate function analysis suggested that the best predictors for distinguishing between pass and fail in the 15-km march were height (0.604), right-hand grip strength (0.524), bench press mass (0.513), body mass (0.265), leg press mass (0.218) and %Vo_{2max} required to successfully complete the 15-km march (0.190). On this basis, a successful female soldier will generally be taller, weigh more, have strong grip strength, and be able to bench and leg press a greater load when compared to an unsuccessful female soldier.

Table E2. Physical characteristics of female soldiers separated by pass/fail on the 15-km march

Physical Characteristics	*n*	*Fail*	*n*	*Pass*
Height (cm)	16	163.2 ± 4.3	11	168.9 ± 4.9*
Mass (kg)	17	61.0 ± 5.6	11	69.1 ± 8.2*
Leg Press (kg)	17	94.0 ± 10.8	11	108.3 ± 16.4*
Bench Press (kg)	17	46.5 ± 10.5	11	59.1 ± 11.3*
Push-ups	16	23.1 ± 7.6	10	26.1 ± 6.8
Right hand grip strength (kg)	16	31.3 ± 3.4	11	37.6 ± 4.6*
Left hand grip strength (kg)	16	29.9 ± 3.1	11	34.8 ± 5.0*
%Vo_{2max} at 5.5 km/hr	17	63.6 ± 5.6	11	57.8 ± 4.5*
Vo_{2max} (l/min)	17	2.5 ± 0.3	11	2.9 ± 0.3*

*Difference between pass/fail groups ($P < 0.05$)

E.3 RDJ Performance – Baseline

A direct discriminate function analysis was performed using two physical characteristic variables as predictors of membership in two groups. Only those physical characteristics that were significantly different between groups, i.e. height and right-hand grip strength, were chosen as it is expected that they may be important predictors for discriminating between female soldiers that pass the RDJ and those that don't. Left-hand grip strength was dropped from the analysis because it was highly correlated with right-hand grip strength (pass, r=0.90; fail, r=0.77). The analysis suggested that the best predictors for distinguishing between pass and fail in the RDJ are height (-0.91) and right-hand grip strength (-0.19). Hence, a successful female soldier will be taller and have stronger forearm strength than an unsuccessful female soldier.

In November only 4 of the 17 females that could not complete the RDJ remained. Of these four only one female could successfully negotiate the RDJ in November after specialised physical training. However, in August no measure (height, push-ups, bench press, etc) could account for the lack of success. The height of the three other females was 158 cm. While alterations in technique would theoretically improve these smaller individuals' success rate, much tuition would be needed without guaranteed success. It should be noted that this was not the common RDJ course that is used Australia-wide. Also, there seems little rationale in conducting extensive training to pass an assessment (RDJ) that attempts to give some indication of a soldier's movement ability, rather than more specialised operational training or general strength and endurance training. Furthermore, considering females are not currently employed in combat roles, the inability of some individuals to scale the wall with weapon and webbing (10 kg) seems of little importance to their current employment success.

Table E3. Physical characteristics of female soldiers separated by pass/failure to complete the RDJ with webbing and weapon

Physical Characteristics	*n*	*Pass*	*n*	*Fail*
Height (cm)	10	169.3 ± 4.7	17	162.7 ± 4.3*
Mass (kg)	11	65.3 ± 9.9	17	63.1 ± 6.2
Leg press (kg)	11	98.9 ± 16.8	17	101.3 ± 14.0
Bench press (kg)	11	53.8 ± 12.8	17	49.9 ± 12.2
Push-ups	10	23.9 ± 6.8	17	24.8 ± 7.7
Right hand grip strength (kg)	10	36.6 ± 6.2	17	32.6 ± 3.8*
Left hand grip strength (kg)	10	34.7 ± 5.8	17	30.5 ± 3.0*
Vo_{2max} (ml/min/kg)	11	41.8 ± 3.3	17	40.3 ± 3.2
Vo_{2max} (l/min)	11	2.7 ± 0.4	17	2.5 ± 0.3

*Difference between pass/fail groups ($P < 0.05$).

E.4 RDJ Performance – Post 15-km March

- Two males failed to complete the RDJ after the 15-km march; one due to blisters and the other did not complete the 15-km. All other males completed the RDJ post 15-km march with a mean time of 64.84 ± 11.8 sec and a range of 44.80-97.82 sec.
- The mean decrement in RDJ performance for males was 12.96 sec, which represents a 24% reduction. Seven males were within 5 sec of their baseline RDJ performance times after the 15-km march.
- Ten of the twelve females that could complete the RDJ with webbing at baseline also completed the RDJ after the 15-km march with webbing. One female needed to drop her webbing post march, while another stopped the march at 5.5km, although she still completed the RDJ within 10 sec of her baseline performance.
- The mean time for the females completing the RDJ with webbing at the end of the march was 117.18 ± 36.55 sec with a range of 73.00-177.57 sec.
- The fastest female completed the RDJ in 73 sec after the march, which bettered seven males.

E.5 Summary of Results for Initial Gender Comparisons

- Male soldiers exhibited greater scores for all physiological assessments than female soldiers including those in which body mass was taken into account, whereas females exhibited greater Sit-and-Reach and skin-fold thickness scores.
- The majority of females (57%) could not complete the RDJ with weapon and webbing.
- Males completed the RDJ in a faster time than females with one female bettering the slowest three males.
- Three males (9%) did not complete the 15-km march in 165 min, although two of these soldiers seemed to misjudge their marching speed, whereas ten females (36%) completed the 15-km march in 165 min.
- The majority of combat soldiers (79%, all infantry) passed the proposed infantry-based post-march RDJ barrier time of 70 sec, whereas only 30% of non-combat male soldiers passed.

- No female soldier passed the infantry-based RDJ barrier time. One female was close to the 70-sec barrier, completing it in 73 sec, which was faster than seven males.

Annex F: Effect of Specialised Physical Training

F.1 Generic Physical Fitness Assessments

Table F1. Physiological assessments of males (n=13) and females (n=9) in the specialised physical training groups before and after physical training

	August		**November**	
	Males	**Females**	**Males**	**Females**
Leg Press (kg)	139.8 ± 25.6	101.1 ± 15.5	162.8 ± 24.8*	115.3 ± 12.9*
Leg Press (kg/kg body mass)	1.71 ± 0.28	1.56 ± 0.15	2.00 ± 0.45*	1.81 ± 0.22*
Bench Press (kg)	117.1 ± 26.1	52.8 ± 11.8	133.6 ± 28.1*	60.6 ± 16.2*
Bench Press (kg/kg body mass)	1.42 ± 0.22	0.81 ± 0.12	1.61 ± 0.25*	0.93 ± 0.15*
V_{O2} (l/min)	3.82 ± 0.53	2.65 ± 0.41	3.98 ± 0.53	2.89 ± 0.38
V_{O2} (ml/kg/min)	46.7 ± 5.3	40.7 ± 2.5	48.6 ± 3.9	45.2 ± 3.4*
R. Hand (N)	52.8 ± 6.5	35.9 ± 6.2	50.0 ± 7.4	34.3 ± 7.1*
R. Hand (N/kg body mass)	0.65 ± 0.09	0.55 ± 0.05	0.62 ± 0.13	0.53 ± 0.09
L. Hand (N)	52.2 ± 6.1	33.3 ± 6.3	51.0 ± 8.0	32.0 ± 5.9*
L. Hand (N/kg body mass)	0.65 ± 0.09	0.51 ± 0.04	0.63 ± 0.12	0.49 ± 0.04*
Static Lift (N)	140.6 ± 19.3	84.7 ± 14.7	155.8 ± 22.8*	93.6 ± 17.8
Static Lift (N/kg body mass)	1.74 ± 0.22	1.30 ± 0.11	1.91 ± 0.22*	1.43 ± 0.19
Peak Power (Watts)	778 ± 69	490 ± 57	793 ± 124	518 ± 81
Peak Power (Watts/kg body mass)	9.67 ± 1.33	7.59 ± 0.87	9.80 ± 1.75	7.97 ± 1.22
30-sec Work (kJ)	17.5 ± 1.7	11.5 ± 1.1	17.6 ± 2.5	12.4 ± 1.6
30-sec Work (kJ/kg body mass)	0.22 ± 0.03	0.18 ± 0.02	0.22 ± 0.04	0.19 ± 0.02
Push-ups	41 ± 8	23 ± 5	39 ± 16	27 ± 5
Pull-ups	10 ± 4	1 ± 1	11 ± 6	1 ± 2
Skin folds (sum of 4; mm)	60.6 ± 24.6	76.5 ± 17.3	61.9 ± 29.0	65.7 ± 13.5*
Sit-and-Reach	1.1 ± 11.1	11.9 ± 9.5	0.1 ± 9.1	12.8 ± 5.9

Values are means ±SD. * Difference between August and November ($P < 0.05$).

Table F2. Physiological assessments of males (n=6) and females (n=3) in the Control groups before and after physical training

	August		November	
	Males	**Females**	**Males**	**Females**
Leg Press (kg)	142.1 ± 18.36	105.2 ± 8.9	150.2 ± 14.6	109.4 ± 13.3
Leg Press (kg/kg body mass)	1.78 ± 0.32	1.70 ± 0.16	1.89 ± 0.34	1.75 ± 0.02
Bench Press (kg)	123.3 ± 26.4	56.1 ± 15.6	121.3 ± 43.0	56.5 ± 22.0
Bench Press (kg/kg body mass)	1.52 ± 0.26	0.89 ± 0.15	1.49 ± 0.42	0.88 ± 0.26
V_{O2} (l/min)	3.82 ± 0.53	2.75 ± 0.50	4.26 ± 0.42	2.88 ± 0.65
V_{O2} (ml/kg/min)	49.7 ± 4.3	44.1 ± 3.2	52.8 ± 5.6	45.6 ± 4.8
R. Hand (N)	58.4 ± 5.3	38.0 ± 3.5	53.8 ± 7.7	37.3 ± 0.6
R. Hand (N/kg body mass)	0.71 ± 0.06	0.61 ± 0.04	0.67 ± 0.08	0.60 ± 0.08
L. Hand (N)	55.8 ± 8.0	35.3 ± 4.0	50.5 ± 10.2	35.0 ± 3.5
L. Hand (N/kg body mass)	0.68 ± 0.08	0.57 ± 0.02	0.62 ± 0.08	0.56 ± 0.04
Static Lift (N)	146.8 ± 12.2	75.0 ± 11.4	160.7 ± 23.4	107.3 ± 21.0*
Static Lift (N/kg body mass)	1.79 ± 0.21	1.20 ± 0.09	2.01 ± 0.34	1.72 ± 0.32*
Peak Power (Watts)	772 ± 58	520 ± 91	745 ± 32	536 ± 109
Peak Power (Watts/kg body mass)	9.37 ± 0.67	8.30 ± 0.72	9.33 ± 1.07	8.50 ± 0.68
30-sec Work (kJ)	17.4 ± 1.2	11.8 ± 2.1	17.3 ± 1.0	12.6 ± 2.8
30-sec Work (kJ/kg body mass)	0.21 ± 0.02	0.19 ± 0.01	0.22 ± 0.03	0.20 ± 0.02
Push-ups	41 ± 10	27 ± 11	41 ± 10	27 ± 14
Pull-ups	11 ± 6	2 ± 3	10 ± 5	2 ± 3
Skin folds (sum of 4; mm)	52.0 ± 16.0	59.0 ± 23.2	50.5 ± 15.7	66.2 ± 20.0
Sit-and-Reach	-1.6 ± 9.7	4.7 ± 12.0	2.1 ± 6.8	7.5 ± 7.6

Values are means ±SD. * Difference between August and November ($P < 0.05$).

Annex G: Issues Related to the Current CFA Policy

At present, Land Headquarters (LHQAUST SIC BAA TRG OU 02042/99) stipulates that a CFA should be conducted once a year, consisting of a 15-km march to be completed in 165 min whilst carrying 35 kg for combat soldiers, 20 kg for non-combat soldiers or 30% of a soldier's body mass if their body mass is less than 70 kg. Furthermore, the RDJ course should be attempted within the 24-hr period of completing the march. The rationale for smaller soldiers carrying lighter loads seems appropriate in a team/section/unit situation; however, there will be a minimum mass that a solider will have to carry for self sustainment, i.e. protective equipment, weapon, ammunition, rations and water. The precise load mass can be established from task analysis work activity or the particular task that the CFA endeavours to simulate. This issue fell outside the scope of the current project, although the outcomes of the DPE-lead Physical Employment Standards (PES) project may shed further light on this issue. However, the PES, in the first instance, will only assess combat corps and will not be completed for at least four years. The aim of this annex is to provide comment and stimulate discussion on the future structure and administration of the CFA.

G.1 Energy Requirements – Those Currently at Risk

The data from the currently reported study had all soldiers, regardless of corps, carrying 35 kg, which is not in agreement with current CFA policy for non-combat corps. Therefore, percentage work intensities were recalculated from the soldier's predicted maximal oxygen uptakes (Vo_{2max}, maximal energy expenditure or work capacity) and the required energy cost of carrying 20 kg for non-combat corps and 30% body mass for those <70 kg. Subsequently, if the CFA was conducted as per currently stipulated, females would have worked at 48.6 ± 3.9% Vo_{2max} (41.1-56.1% vs. 55-70%), male non-combat at 40.9 ± 3.1% Vo_{2max} (range: 36.3 to 46.9%) and combat at Vo_{2max} 47.6 ± 5.0% (range: 40.0 to 55.2%). Therefore, it is likely that these particular soldiers could complete the 15 km in the prescribed time. However, while most soldiers (70%) would theoretically commence the 15-km at an intensity below 50% of their maximal capacity, there is potentially three risk groups identified from the current 2.4-km-run BFA standards. A number of assumptions have been made when determining those soldiers currently at risk:

i) To safely complete the CFA and maintain an adequate degree of physical capability at the end of the 15 km, soldiers should not commence the march at >50% Vo_{2max}. If the duration of the activity was reduced to 2 hr, then 60% Vo_{2max} would be permissible; similarly for 1 hr, 70% Vo_{2max} would be acceptable.
ii) The BFA is run maximally, such that the 2.4 km could not be completed any quicker.
iii) The energy requirement of walking with the load at 5.5 km/hr is accurately predicted from the equation provided by Pandolf[1].
iv) The 15-km course surface is a flat dirt road.

[1] Pandolf KB, Givoni B & Goldman RF (1977). "Predicting energy expenditure with loads while standing or walking very slowly. *Journal of Applied Physiology* 43:577-581.

v) Combined mass of clothing, boots and weapon is 7 kg; therefore, the remainder of the load mass would be carried in the webbing and pack.

G.1.1 Low Body Mass

The first risk group is those combat soldiers that possess a low body mass, such that the lighter the soldier, the greater difficulty in carrying a heavy load. This is theoretically described in the following example involving three soldiers of different body mass (65, 80 and 95 kg). The oxygen consumption of these three soldiers walking at 5.5 km/hr without the 35-kg load is 1.02, 1.26 and 1.49 l/min respectively. This trend is obvious since more energy is required to move a greater mass. When a 35-kg load is carried, the required oxygen consumptions are elevated to 1.59, 1.78 and 1.99 l/min respectively. Subsequently, the proportionate increase in oxygen cost is far greater for the lighter soldier; 56% vs. 41% vs. 25% respectively. If all three soldiers were to work at the same relative intensity, i.e. 50% Vo_{2max}, the 2.4 km BFA times would need to be 10:30, 11:30 and 12:30 respectively. Therefore, a 21-year-old 65-kg combat soldier that can just pass their BFA (11:18; see Table G1) will be working at >50% Vo_{2max} at the start of the 15-km march. Similarly, a 31-year-old 80-kg soldier that can just pass their BFA (12:18) will also commence the 15-km at a work intensity >50% Vo_{2max}. As can be seen in Table G2, those combat males >21 yr with a body mass <75 kg that only just pass the BFA will be starting the CFA at >50% Vo_{2max}.

Table G1. Current 2.4 km BFA pass standards

Age	Males	Females
<21	10:48	12:27
21-25	11:18	13:30
26-30	11:48	14:18
31-35	12:18	15:12
36-40	12:42	16:06
41-45	13:12	16:54
46-50	13:48	17:42
51+	14:30	18:48

G.1.2 Combat Soldiers >36 Yr

The above example also highlights the second group at risk - those combat males >36 yr that can only just pass their 2.4 km BFA regardless of their body mass. A 41-year-old combat male that completes the 2.4 km run in 13:12 would commence the CFA at 57% Vo_{2max}, most likely increasing to 70% Vo_{2max} by the end of the 15 km. Subsequently, the soldier's heart rate would be expected to be ~160-170 beats/min, which corresponds to 89-94% maximum heart rate.

G.1.3 Female Soldiers >26 Yr

The third group are females that only meet the minimal requirements of the 2.4-km BFA. A 65-kg female (26 yr) carrying 20 kg would commence the CFA at 55% Vo_{2max}. Similarly, a 31-year-old female would be initiating work at 59% Vo_{2max}, whereas a 36-year-old female would start the CFA at 62% Vo_{2max}.

Table G2. Required 2.4 km BFA times as a function of body mass. Shaded areas indicate sufficient BFA times to commence CFA at 50% maximal capacity

Body Mass	BFA Time												
	15:00	14:30	14:00	13:30	13:00	12:30	12:00	11:30	11:00	10:30	10:00	9:30	9:00
50													
55													
60													
65													
70													
75													
80													
85													
90													
95													
100													

Green – current combat corps (35 kg); Yellow – LAND125 LC1 (25 kg); Orange – current non-combat corps (20 kg or 30% body mass for <70 kg); Red – not capable of 50% work intensity for current non-combat corps

Subsequently, the Regiments and Battalions that are required to complete a CFA on an annual basis should be encouraged to implement gender- and age-independent pass times for the BFA that are indexed to the soldier's body mass and corps, i.e. combat vs. non-combat; Table G3. This screening would provide a safety net to ensure that no soldier is placed at undue injury risk during CFA administration and would not be aimed at replacing the Army Individual Readiness Note (AIRN) standards, especially if the AIRN standard is higher than the CFA-based standard, which would be the case for combat soldiers >80 kg and <30 yr.

Table G3. Proposed 2.4 km BFA times for current CFA and future load carriage masses, indexed to body mass and corps

	Combat Units		Non-Combat Units	
Body Mass	**Current (35 kg)**	**LC3 (54.5 kg)**	**Current (20 kg- 30%)**	**LC1 (25.5 kg)**
50	9:04	6:06	12:57	10:49
55	9:38	6:46	12:57	11:17
60	10:08	7:22	12:57	11:40
65	10:33	7:54	12:57	12:00
70	10:56	8:23	13:06	12:17
75	11:15	8:50	13:18	12:32
80	11:33	9:14	13:29	12:46
85	11:48	9:36	13:38	12:57
90	12:02	9:55	13:46	13:08
95	12:15	10:13	13:54	13:17
100	12:26	10:29	14:00	13:26

G.2 The Appropriate CFA Load Mass, Pace and Distance

Trade-task analyses are required to be performed to assess the desired outcomes of the CFA. That is, what does the CFA task replicate for this all-corps assessment?

G.2.1 Infantry and Associated Trades

Superficially, the CFA seems highly relevant to infantry and associated corps. The load of 35 kg has been referenced in the latest LAND125 documentation as that which would be carried for an operation lasting up to 12 hours (LC2). However, the LAND125 load configuration is somewhat different in that no pack is employed, but rather chest and standard webbing. The currently employed 35 kg was formulated for a 3-day operation (LC3). The major discrepancy between the envisaged LC3 employed in the CFA study and the LAND125 (LC3), which is 50 kg, is the inclusion of body armour and helmet. Subsequently, it is extremely unlikely that infantry soldiers would be able to carry 50 kg at 5.5 km/hr over a 15-km distance. As can be seen in Table G3, the 2.4-km BFA would need to be completed at an exceptionally quick pace. These load mass discrepancies raises the question of whether or not the CFA for infantry and associated corps be at 50 kg, and obviously at a slower pace, or remain at 35 kg? Furthermore, if the load mass remains at 35 kg, should it consist of body armour, helmet, chest and standard webbing and not include the pack?

Apart from the load mass issue, consideration is also needed as to the appropriate distance and marching pace. It is understood that infantry could regularly conduct marches far in excess of 15 km; therefore, an increased distance could be considered. Also consideration could be given to the addition of a second 15 km on the day after the first march as is conducted by the UK Army.

G.2.2 Other Combat Trades

Consideration should be given to the appropriateness of the 35 kg to the other combat trades. Although, for those that conduct similar operations to infantry, i.e. reconnaissance scouts, forward observers, etc., the 35-kg load mass seems appropriate. However, it may not be appropriate for tank crew to be carrying 35 kg in pack and webbing, but rather if the role of the CFA is to assess the soldier's ability to retreat from an ambush in which their tank was rendered inoperable, then a lighter load (webbing, rations, weapon, ammunition) at potentially a quicker pace could be more suitable. Alternatively, if the CFA objectives are to assess the soldier's ability to patrol, regardless of corps, then the duration of this patrol will dictate the load carried, i.e. <12 hr does not require sleeping equipment, requires less rations and water compared with a 3-day patrol, etc. Subsequently, it is conceivable that only 20-25 kg would be carried with a small pack and standard webbing or no pack with chest and standard webbing. Furthermore, patrolling is typically conducted at a much slower speed than 5.5 km/hr.

G.2.3 Non-Combat Trades

For the combat-support and other non-combat corps, a thorough trade-task analysis identifying those tasks that are relevant to load carriage over prolonged distances would aid in determining the appropriate CFA parameters for these trades. As mentioned above, if the CFA objective is to assess a soldier's ability to patrol, then it is likely that this is not for periods >12 hrs; therefore, a pack is not necessary. Similarly, does the CFA task represent a retreat from ambush? The critical issue related to the load mass is whether or not body armour and a ballistic helmet would be worn. These items add considerable mass (~10 kg) and for the smaller, less fit soldier could easily make the task unachievable.

Webbing only would be beneficial for the smaller soldiers since it was observed on a number of occasions, during data collection, that the pack forced down the webbing to below the buttocks, which would result in the majority of the load being borne on the shoulders. Shifting the loading from the shoulders to the hips reduces strain on the upper body muscles, shoulder contact pressures, subjective discomfort, the potential for herniate and 'slipped' disks, and has been suggested to improve marching efficiency.

G.3 CFA Implementation, Structure and Philosophy

While sufficient physical training is necessary and recommended for most soldiers prior to conducting the current CFA, it is not advantageous to emphasise an intensified physical-training period to pass an assessment administered once per year. Land Headquarters recommend a 12-week CFA training program, which appears to be appropriate. However, anecdotally, many participants in this study and the 3 Brigade study[2] commented that

[2] Cotter JD, Roberts WS, Amos D, Lau W-M & Prigg SK (2000). Soldier performance and heat strain during evaluation of a Combat Fitness Assessment in Northern Australia. *DSTO Technical Report DSTO-TR-1023*

they have very limited CFA-specific physical training administered prior to conducting the CFA.

The pass level of the assessment, i.e. the combination of load mass, distance and speed, should also be given consideration, i.e. should represent worse-case scenario in regards to physical demands that are irregularly experienced or more routine scenarios or physical demands that are less than those regularly experienced. For instance, if infantry soldiers regularly carry heavier loads (>35 kg) at faster speeds (> 5.5 km/hr) over longer distances (>15 km) than the current CFA pass level, then for this particular corps the current CFA format is not adequate. Similarly, for those soldiers not in infantry-related trades, if the expectation is to determine a soldier's ability to conduct a 3-hr patrol, then the load should be no more than 19 kg (if body armour and helmet is not worn) and the pace and distance could be questioned. If the CFA pass level is currently set at minimum expected capability levels, then theoretically no further physical training would be required above that employed in a desired trade-task-based physical training regimen. The philosophy of increasing physical training load in order to pass an assessment is somewhat undesirable since this reinforces that the assessment is the 'gold standard' rather than the 'minimum standard'. Furthermore, it is feasible that soldiers only transiently achieving the CFA standard once per year would for the remainder of the year, when the physical training reverts back to regular levels, no longer pass the assessment, therefore providing a false-positive indication of the soldier's physical capabilities for the majority of the year. These reservations are similar to those recently raised concerning the BFA[3].

It is imperative that the future CFA structure should be trade-specific with the assessments being realistic in respect to trade-task physical requirements. Subsequently, trade-specific physical training programs would focus on physical performance improvements related to the trade tasks rather than improving the physical performance to a less relevant physical assessment. While the Physical Employment Standards project will address these raised issues, the Infantry outcomes are not expected until late 2005 with the other combat trade outcomes occurring 2006-2008 and there are no definitive plans for the non-combat trades. Therefore, if Land Command is not content with the current CFA format, further clarification is needed to determine the purpose and outcomes of the assessment to recommend appropriate modifications, which may also affect the BFA.

If the CFA is viewed as a competency-based assessment and it provides an indication of combat-readiness, then it should be conducted in similar environmental conditions to expected operations. Regularly, the 15-km march is conducted in the early part of the morning in the cooler months of the year. However, this could overestimate the soldier's competency, especially if they are required to operate in more extreme environments such as in the warmer part of the day. By conducting the two CFA trials in August and November, some indication of environmental conditions on march success and physiological strain was established. It is clear that the environmental conditions may

[3] Groeller H, Armstrong K, Fogarty A, Gorelick M & Taylor N (2002). A scientific review of the Basic Fitness Assessment. *UOW-HPL-Report 008. Human Performance Laboratories (Australia), University of Wollongong.*

prevent the march to be completed in 165 min due to the incidence of hyperthermia. Improvements in physical fitness and heat acclimatisation may diminish the incidence of hyperthermia if heat loss mechanisms were sub-optimal. Nevertheless, if the heat production is greater than the heat loss, hyperthermia will result. Therefore, as expressed by Cotter et al.[2], CFA marching speed should be indexed to environmental conditions. Further research is required for setting these reduced progression rates in hotter conditions.

G.4 Comparisons with other Armies' Assessments

The US Army appears not to have a CFA-type assessment for their soldiers, but rather relies on their BFA-equivalent 3.2-km run, although the US Field Manual (FM) 21-18 recommends maximum fighting loads of 22 kg and maximum approach loads of 33 kg and prescribes a marching speed of 4 km/hr. Other NATO armies conduct various forms of marching tests with various loads and distances - Canada 3.2 km with 16-18 kg, also 13 km with 24.5 kg at 5.3 km/hr, France 8 km with no load, UK 12.8 km with 20 kg, Denmark 15 km with 30 kg. Furthermore, the UK Army was advised to screen all soldiers by employing a 12.8-km march at 6.4 km/hr with load masses based on unit - Infantry 25 kg, 20 kg for the other combat trades and 15 kg for all other corps[4]. However, on 1st April 1999, the UK Army replaced the Combat Fitness Test (CFT) with the Advanced Combat Fitness Test (ACFT). The CFT consisted of a 12.8-km march in 115 min (6.7 km/hr) with 16 kg, whereas the ACFT consists of a 20-km march over varied terrain (at least 6 km to be off tarmac/roads) in 210 min (5.7 km/hr) with 30 kg. In addition, a second 20-km march on day two is to be completed within 180 min (6.7 km/hr) carrying 20 kg. However, this assessment appears to be quite infantry specific and is not relevant to the current Australian CFA, which is an all-Corps activity for all personnel in Land Command.

It appears that the current CFA format is similar to that employed by other armies, especially the UK. However, the UK 12.8 km, while slightly shorter than the CFA, actually requires a greater rate of energy expenditure even though the load mass is 5 kg lighter for the non-combat soldier due to the faster marching pace. Considering that equipment integration issues (pack and boot fitting) are most likely the greatest limiting factors, rather than the physiological systems, during load carriage assessments (especially for those that are not familiar with carrying a pack), a webbing-only lighter load at a faster speed may be a beneficial option in relation to reducing injuries.

G.5 RDJ Modification

The replacement of the broad jump pit in the modified-RDJ course will theoretically reduce the knee and ankle injury risk, especially for the smaller soldiers who can just clear the pit. The replacement obstacle, running down a sloped-pit and climbing out, added a further upper body strength activity similar to the wall. However, the trial obstacle created drainage problems and it is recommended that the pit activity be modified to an above

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[4] Rayson MP & Holliman DE (1995). Physical selection standards for the British Army: Phase 4. Predictors of task performance in trained soldiers. *Defence Research Agency, UK. DRA/CHS/PHYS/CR95/017.*

ground activity. The go-to-ground obstacle introduces new movement requirements such as going to ground during fire and movement in a combat situation. Despite the reduction of height of the wall to 1.5 m, for male soldiers the introduction of the flat wall is the greatest discriminator, such that smaller soldiers are unable to negotiate this obstacle with weapon and webbing. This modification resembles an urban terrain obstacle. While alterations in technique would theoretically improve these smaller individual's modified-RDJ success rate, much tuition would be needed without guaranteed success. Furthermore, as highlighted above, the appropriateness of specialised training for a specific assessment (RDJ), rather than more specific operational training or general strength and endurance training, needs to be questioned. This can be addressed by assessing the importance of a soldier's movement ability in accomplishing their employment success in their appropriate army role. However, to test all Land Command soldiers' physical occupational fitness ability in an urban terrain environment is logistically impossible. Consequently, the RDJ remains a simple test that simulates fire and movement activities in an urban terrain environment.

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Combat Fitness Assessment, trade task analysis, physical competencies, thermal strain, load carriage.

19. ABSTRACT

We investigated the physical and occupational capabilities of male and females soldiers before and after 12 weeks of specialised physical training. The Combat Fitness Assessment (CFA) was employed to assess the infantry-related occupational capabilities, which consisted of a 15-km march at 5.5 km/h followed by the Run-Dodge-Jump (RDJ) activity. All soldiers (35 males and 28 females) carried 34.6 kg, which was based on the requirements for a 3-day operation. Physiological assessments of muscular strength and endurance, and aerobic and anaerobic capacities were also performed. All males could complete the RDJ in a rested state, prior to the march, whereas the majority of females (57%) could not complete the RDJ with weapon and webbing. The majority of males (91%) completed the 15-km in 165 min, whereas fewer females could complete the march successfully (36%). All infantry soldiers and the majority of combat-corps soldiers (79%) could complete the post-march RDJ in less than 70 sec, whereas the fastest female required 73 sec to complete the course. The specialised physical training improved strength and aerobic capacity for the female group and strength only for the male group, although the female scores remained below those of the males. These improvements did not translate into improved success in the infantry-based CFA task, i.e. no female could pass the 70-sec RDJ barrier. Post-specialised physical training one female completed the post-march RDJ in 73 sec, while another Control female achieved an RDJ time of 65 sec after the physical training period. Therefore, assuming that this small sub-group of female soldiers are representative of the whole Army, it is likely that a small number of female soldiers are physically able to complete this assessment within the same performance limits as current infantry soldiers. The elevated environmental heat stress encountered during the post-specialised physical training CFA potentially masked any possible benefit gained from the physical training program. Combined with the dramatic drop in soldier numbers it is difficult to provide definitive conclusions as to the effectiveness of the specialised physical training program. CFA administration should be planned for the cooler less humid months to diminish the likelihood of thermal injuries. If the CFA is conducted in hotter and more humid conditions, longer completion times (allowing rest periods), reduced distance and lighter loads should be considered.